IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, OLD WASTE CALCINING FACILITY
SCOVILLE VICINITY
BUTTE COUNTY
IDAHO

HAER NO. ID-33-C
INEEL-97-01370

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historical American Engineering Record
National Park Service
Western Region
Department of the Interior
Seattle, Washington 98104

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HISTORICAL AMERICAN ENGINEERING RECORD

IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY,
IDAHO CHEMICAL PROCESSING PLANT,
OLD WASTE CALCINING FACILITY, CPP 633 HAER NO. ID-33-C

Location: Within the Idaho National Engineering and Environmental Laboratory at the Idaho Chemical Processing Plant, approximately 53 miles west of Idaho Falls, Idaho, in Butte County, the NE 1/4 of NW 1/4 of SW 1/4 of Section 19, Township 3 North, Range 30 east, Boise Meridian.

Date of Construction: Completed in 1961

Designer/Architect and Builder: The Fluor Corporation, Ltd.

Present Owner: United States Department of Energy

Present Use: Shut down; in process of decontamination and demolition pursuant to federal and state laws

Significance: The Waste Calcining Facility was the first plant in the world to demonstrate successfully a practical method of transforming liquid high-level radioactive waste into a solid form. After its first successful campaign from December 1963 to October 1964, in which over 500,000 gallons of liquid were reduced to solid calcine at a volume reduction of about 7 to 1, the Waste Calcining Facility continued operating until 1981 when a larger-capacity, updated facility took its place to continue the same process. Calcining eventually will transform all high-level radioactive liquid waste at INEEL into solid form by 2012.

The liquid waste feeding the Calcining Facility was the acidic by-product of chemical process operations that recovered enriched uranium from spent reactor fuel. In liquid form, the by-product waste was stored in steel tanks that had a design life of 50 years. Solid calcine, on the other hand, is dry, less corrosive, safer, and cheaper to store because of its reduced volume. In its 18-year life, the Waste Calcining Facility converted four million gallons of liquid waste to solid calcine at a volume reduction ratio averaging about 10 to 1.

Partly because of the early conversion of high-level liquid waste to solid form, leakage into the soil from corroded tanks has been avoided at INEEL.

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1718 North 17th Street
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Date: March 30, 1998

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PART ONE

INTRODUCTION TO THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

The Atomic Energy Commission (AEC) established the National Reactor Testing Station (NRTS) in 1949 as a place where nuclear reactor experiments could take place without great risks to nearby populations. It chose this site in eastern Idaho on the desert of the Snake River Plain for its abundant supply of subsurface water and its relative isolation from densely populated settlements. The land already was in public ownership; the U.S. Navy had used it as a proving ground in connection with its Pocatello Ordnance Depot during World War II. The residences, barracks, warehouses, and other buildings at the proving ground became the Central Facilities Area of the new reactor testing station, providing communications, supplies, security, shops, transportation, and many other services to the various tests and experiments. This area is in the southwestern section of the site, just a few miles from State Highway 20. (See Vicinity Map in Appendix B.)

The entire reservation consists of about 890 square miles. Its business was to experiment with and thereby accumulate and disseminate knowledge about nuclear reactors. Research missions have included weapons systems for the Department of Defense and investigations leading to economic and safe nuclear reactors for the commercial power industry. The Atomic Energy Commission hired a private contractor to operate the central management functions of the installation, while subcontractors built individual reactors and related experiments and projects. In 1974, the name of the NRTS was changed to Idaho National Engineering Laboratory, or INEL; in 1997, to Idaho National Engineering and Environmental Laboratory (INEEL).[1]

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[1] For additional background information on the establishment and description of the NRTS site, see introductory section of HAER No. ID-32-A "TAN Hanger 629," or Richard Hewlett and Francis Duncan, Atomic Shield, 1947-1952, Volume II of a History of the United States Atomic Energy Commission (Philadelphia: University

Distributed around the site are several compact centers of activity, each confined within security fencing, guarded entry gates, and other controls for physical safety and national security. Each center is isolated, surrounded by miles of the flat desert landscape. Most facilities were situated to avoid potential accidental or diluted radioactive releases from other facilities upwind, considering the most predominant direction of the winds.

The initial program of reactor testing and development at NRTS consisted of four programs. Each became the nucleus of one of the activity centers on the site. The two most pertinent to the Waste Calcining Facility were the Test Reactor Area (TRA), where the Materials Testing Reactor was located, and the Idaho Chemical Processing Plant (abbreviated hereafter as CPP).[2] The CPP is located about three and a half miles north of the Central Facilities Area on the east side of a connecting road named Lincoln Highway. The TRA is another mile and a half north and on the west side of the highway.

PART TWO
THE MATERIALS TESTING REACTOR FUEL CYCLE

The Materials Test Reactor (MTR) was one of the earliest projects established at the NRTS, beginning operations in 1952. The mission of this reactor was to irradiate a wide range of materials in test loops, beam holes, and compartments within the reactor. The object of the tests was to learn more about the metals and fuels that would make up the components of future reactors.

During World War II, the Manhattan Project had perfected an atomic bomb, but it was now time to consider peaceful potentials for the atom. One such use was for electrical power generation. However, the scientific and engineering community had practically no base of information about what kinds of reactor configurations would be safe and economical, what kinds of materials would perform under intense radiation, or what kinds of fuels could safely be used for civilian power reactors. The MTR would test materials and begin to answer these and other complex reactor physics questions.

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of Pennsylvania Press, 1969.)

[2] Some reference documents use the name Waste Calcination Facility.

The operating objective of the MTR was to direct a very high flow, or flux, of neutrons to the test samples. This was the only efficient way to discover in a few weeks or months what years of radiation might do to a component in an operating power plant.

The MTR itself used highly enriched uranium fuel made of uranium oxide. "Highly enriched" contrasts with "natural" uranium. Any sample of natural uranium contains two important isotopes.[3] The most abundant is U-238, which is 99.28 percent of the sample, and does not fission ("split") when bombarded with neutrons. The remaining .71 percent is U-235 and will fission. When bombarded with neutrons, U-235 atoms split, yielding heat, neutrons, two lighter elements, and other particles. If sufficient U-235 atoms are nearby, the newly-released neutrons will split them and thus begin a chain reaction.

Procedures to enrich natural uranium involved removing the U-238 atoms from a sample, thereby increasing the percentage of U-235. This was a very expensive and time-consuming procedure. Fuel manufactured for the MTR was enriched to contain 93.4 percent U-235. For use in the reactor, the enriched uranium was clad in an aluminum alloy, arranged in small plate-like shapes, and assembled for insertion into the core of the reactor. During reactor operation, the non-fissioning fission products accumulated in the fuel and "poisoned" it, or reduced its reactivity. When this occurred, the neutron flux ceased and the fuel had to be replaced.

The operators of the MTR shut the reactor down every 17 days to remove its depleted fuel and replace it with fresh. By this time, less than a fourth of the U-235 had been fissioned, leaving a substantial amount of U-235 in the fuel elements. Rather than discarding this costly material, it was possible to submit it to chemical procedures that would separate the U-235 from the aluminum cladding and other substances that had accumulated in the fuel. This was the mission of the Idaho Chemical Processing Plant, located across and down the road about two miles.

PART THREE
THE IDAHO CHEMICAL PROCESSING PLANT

The Idaho Chemical Processing Plant was designed by the same group of physicists and chemists who had designed the MTR. As a companion facility for the MTR, it was equipped to receive the

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[3] Uranium also contains .01 percent of U-234. It is non-fissionable, does not absorb neutrons, and is of little practical importance in nuclear fuels.

spent fuel elements and extract from them the valuable U-235. The spent fuel was extremely hazardous, containing as it did radioactive elements such as Strontium-90, Cesium-137, and other substances dangerous to human life. At the end of the extraction process, CPP shipped the recovered U-235 to Oak Ridge, Tennessee, for further steps leading to the remanufacturing of fuel elements. The uranium was not a hazard, but the CPP had to store or otherwise dispose of the dangerous residual materials left behind. Another name for the residue was "high-level radioactive waste."

The chemical processes used to recover U-235 took place in a long building known as the Fuel Processing Complex (CPP-601). Using remote-controlled operating methods, workers transferred the fuel elements--cladding and all--from heavily shielded transport casks into a vessel containing nitric acid. Fuel and aluminum dissolved. This aqueous substance was transferred by steam-jet suction to a series of other vessels where chemical solvents such as tributyl phosphate separated the constituents in the liquid. After three major cycles of solvent extractions--in which substantial amounts of water were used and contaminated--the waste materials included high- and low-level liquid wastes, solid wastes, and off-gases.[4] Each of these wastes was treated in a different way. The high-level liquid waste was treated at the Waste Calcining Facility.

High-level liquid waste was pumped to 300,000-gallon stainless steel tanks enclosed in subsurface concrete vaults and further shielded by ten feet of earth. The liquid waste within the tanks consisted mostly of water, but each gallon contained a lethal quantity of radiation. Cooling coils within the tanks maintained the temperature between 120-160 degrees F.

By the time the CPP, operated by the Phillips Petroleum Company for the AEC's Idaho Operations Office, was ready to process spent fuel in February 1953, the earlier optimism for peaceful uses of atomic energy had dissipated. International tensions had steadily risen once more. The Soviet Union had detonated its own atomic device in 1949; the United States had fought Communist expansion in Korea; Soviet and American

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[4] For a more detailed description of the CPP's modified PUREX (Plutonium and Uranium Extraction) process, see Brewer F. Boardman, The ICPP (A Factsheet) (Idaho Falls: Idaho Operations Office, 1957). For a general description of the plant and its operations, see R.B. Lemon and D.G. Reid, "Experience With a Direct Maintenance Radiochemical Processing Plant," Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Volume 9 (New York: United Nations, 1956), p. 532-545.

interests in Europe were in conflict. The Cold War weapons race had begun. The United States poured its resources into weapons development, striving for supremacy in the race.

Elsewhere in the country, the AEC's plutonium-production reactors were busy and expanding. At NRTS, all research missions bent to the compelling needs of national defense. From its original mission of reprocessing only MTR fuel, the CPP was adapted for more flexibility as a multiple-purpose processing plant. Eventually, it would process fuel from weapons-related research, test, propulsion, and power reactors from far beyond the MTR. Its inaugural run included reprocessed fuel from the plutonium-producing Hanford Engineering Works in Washington.

With the first and every succeeding run, a stream of high-level waste inevitably flowed into the stainless steel tanks at CPP. After the first was filled, another was made ready, and then another. By 1997, eleven 300,000-gallon vessels populated CPP's tank farm. Awash in a million gallons of liquid were only ten gallons of radioactive material.[5]

It soon became evident that the amount of nuclear fuel needing to be reprocessed would only grow. After the U.S. Navy launched the Nautilus submarine in the 1950s, it built a large inventory of ships propelled by nuclear power. Research programs at NRTS began testing the safety limits of reactor fuels and core constructions. The AEC and Congress's Joint Committee on Atomic Energy did all they could to nurture a commercial atomic power industry. After the AEC built a successful demonstration power reactor at Shippingport, Pennsylvania, their efforts began to bear fruit, making it clear that new reactors would soon pile up large inventories of spent fuel. These would need reprocessing and result in millions more gallons of liquid waste.

Scientists knew that metal tanks could not be a very long-term method for storing the waste. They regarded the life of a stainless steel tank to be no longer than 50 years because the acids from within or moisture from without would eventually corrode the metal, resulting in leaks into surrounding soils and ground water. Far longer than 50 years was required to sequester the waste because it would be 500 years or more before it could

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[5] To Senator Henry Dworshak from John B. Huff, August 21, 1958; Dworshak Papers, Box 83, File "AEC--Idaho Plant." Also, "Idaho Falls: Atoms in the Desert," Chemical Engineering (January 25, 1960), p. 5. Hereafter cited as "Dworshak Papers."

be considered for discharge to the environment.[6] Chemists in the AEC's national laboratories therefore launched investigations into "interim" and "ultimate" disposal of these wastes.

PART FOUR
CONVERTING LIQUID TO SOLID WASTES

One of the concepts for dealing with the growing volume of liquid waste was to transform it somehow into a dry solid, eliminating the water. This meant designing a process that would concentrate radioactive substances into a dry form, leaving the water clean enough to discharge into the environment. This could be an "interim" step in storing the waste. The volume could be reduced and the hazard of corrosion and leakage minimized. It was also conceivable that the solid form might be rendered even more inert or stable using processes as yet unproven.

Scientists came forth with several ideas for transforming liquid into an inert solid-carrier waste. A 1954 study from Brookhaven National Laboratory suggested that radioactive ions could be made to adsorb and fix upon montmorillonite clay. Other studies proposed fixation in ceramic glazes or "gelling" liquids above the sludges that form in the tanks. Various techniques for solidifying the waste included pot calcining, radiant heat-spray, and rotary-ball kilns. Some proposed to incorporate the wastes into low-melting salts and store the material in underground salt caverns equipped to remove heat. Another optimistic hope was that some breakthrough chemical means of decontaminating the radioactive constituents might be found. At Oak Ridge National Laboratory, workers were investigating the possibility of mixing waste with shale, limestone and soda ash and allowing decay heat to fix the material in a ceramic mass. Still other proposals altogether sidestepped the problem and proposed to discharge it into the oceans or outer space.[7]

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[6] The half-life of Strontium-90 is 25 years; of Cesium-137, 30 years. A half-life is the time required for the radioactivity of a given amount of the element to decay to half its initial value. The process is independent of temperature, pressure, or surrounding chemical conditions. From Samuel Glasstone, Sourcebook on Atomic Energy (New York: Van Nostrand Reinhold Company), p. 147.

[7] See W.S. Ginnell, J.J. Martin, and L.P. Hatch, "Ultimate Disposal of Radioactive Wastes," Nucleonics (December, 1954), p. 14-18; "Outlook for Waste Disposal," Nucleonics (November 1957), p. 155-164; The Waste Calcining Facility at the Idaho Chemical Processing Plant, pamphlet, no date, no author, p. 2; Joseph A.

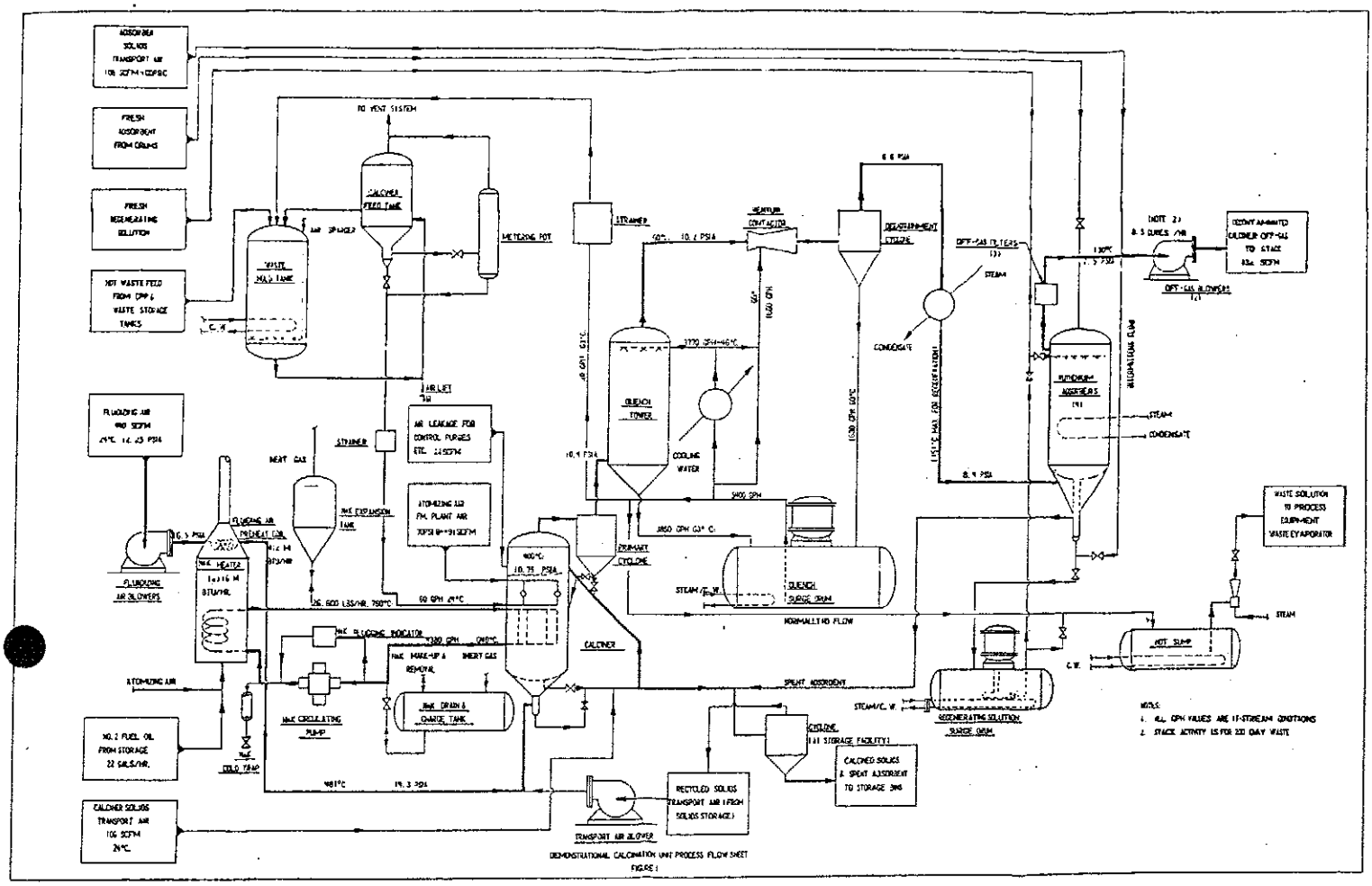

Fig. 1. Calcine Process flow sheet

Source: MacQueen and Stevens, *Design Bases for ICPP Waste Calcination Facility* (Idaho Falls: Report IDO-14462), p. 23.

Lieberman, "Treatment and Disposal of Fuel-Reprocessing Waste," Nucleonics (February 1958), p. 86; and J.I. Stevens, et al, Preliminary Process Criteria and Designs for Waste Calcining Facilities at the Idaho Chemical Processing Plant (Idaho Falls: Phillips Petroleum Company Report No. PTR-177, February 25, 1957), p. 5.

The first liquid-to-solid procedure that the AEC funded on a demonstration scale, however, was the "fluidized-bed calcination process." The program leading to its construction began in 1955. Originally conceived by scientists at Argonne National Laboratory, the method was first tested using simulated radioactive waste at Phillips Petroleum's Chemical Engineering Laboratory at CPP. The process not only solidified the waste, but the solid was granular, free-flowing, and easily handled by pneumatic transport techniques. Phillips engineers proposed conceptual designs for the process in 1956.[8]

To help answer numerous questions about how the waste liquid might react in the various stages of the calcining process, Phillips constructed small models for "bench-scale" experiments. One calciner, only six inches in diameter, continued in use until 1960. Argonne National Lab built a slightly larger model, square in shape and two feet on each side. The engineers needed to produce samples of the calcined product in order to discover its volatility characteristics, reactivity, thermal conductivity, storage behavior, and many other parameters. Using small models, they could develop design criteria for the final scaled-up version of the calciner and the building in which it was to operate.[9]

Design criteria evolved as tests and experiments proceeded. Early criteria were proposed in 1957. Little information was available at the time on how such a plant might be maintained or decontaminated, so the criteria proposed "direct" maintenance. This meant that technicians would use hands-on techniques to do

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[8] See C.E. Stevenson, et al, Waste Calcination and Fission Product Recovery Facilities--ICPP, A Conceptual Design (Idaho Falls: Phillips Petroleum Company Report PTR-106, August 2, 1956); and D.R. Evans, Pilot Plant Studies with a Six-Inch Diameter Fluidized Bed Calciner (Idaho Falls: Phillips Petroleum Company Report No. IDO-14539), p. 2.

[9] PTR-177, p. 29. See also, "Projects Authorized for Idaho Operations Office in Recent Appropriations Bill," Dworshak Papers, Box 70, File "AEC--Idaho Plant." For discussion of the six-inch pilot calciner studies, see D.R. Evans, Pilot Plant Studies with a Six-Inch Diameter Fluidized Bed Calciner (Idaho Falls: Phillips Petroleum Company Report No. IDO-14539). Studies of the two-foot model are reported in B.P. Brown, E.S. Grimmett, and J.A. Buckham, Development of a Fluidized Bed Calcination Process for Aluminum Nitrate Wastes in a Two-Foot Square Pilot Plant Calciner, Part 1, Equipment Development in Initial Process Studies (Idaho Falls: Phillips Petroleum Company Report No. IDO-14586).

repair and maintenance tasks. After a calcining run, some clean-up--such as high pressure steam sprays--would be remotely operated--but trained crews would enter equipment areas with special tools and safety gear to finish the job.

Naturally, the designers wanted the process to be as simple and trouble-free as possible. It would be ideal to store the solids in facilities that could be unattended for a long period of time, but it was premature to design such a facility with the then-current state of knowledge. Thus, the first storage facilities were considered developmental. It was not known yet just what effort would be required to keep the material cool. (Radioactive decay produces heat). It was also not known just what products in the solid might prove to have future value, so the storage container would have to be designed to retrieve the solids for some future processing. And the operation in general had to insure against radioactive particles entering the air or water supply.[10]

Congress appropriated funds in 1957 for the early phases of design. The AEC awarded an architect/engineering contract to the Fluor Corporation, and in 1958, asked Fluor to complete and construct the system. The facility cost about $6 million.[11]

Fluor commenced construction in 1958 and completed the Waste Calcining Facility (WCF) in 1961. When Phillips took control of the building, it began two years of "cold" operations using simulated waste. Such runs illuminated numerous deficiencies in the equipment or the process, all of which were overcome or accounted for in various modifications and adjustments. In addition, the cold runs provided analysts an opportunity to determine what safety precautions were needed to operate the facility. They modeled every possible equipment failure to determine its radioactive consequences. Examples: What would happen if a pipe containing the heating element, NaK, were to rupture inside the calciner vessel? What would happen if the plant had to shut down with radioactive calcine still sitting in the vessel? Would fission product heat cause the vessel to overheat? The answers to these questions led Phillips to install

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[10] PTR-177, p. 7-8.

[11] News release from Idaho Operations Office of the AEC, February 5, 1957; Senator Dworshak Papers, Box 74, File "Legislation--AEC--Idaho Releases." See also "Fluor Gets Contract to Complete Calcination System," Nucleonics (November 1958), p. 27; and L.T. Lakey, et al, ICPP Waste Calcining Facility Safety Analysis Report (Idaho Falls: Phillips Petroleum Company Report No. IDO-14620, 1963), p. ii-1.

appropriate instrumentation, operating procedures, and redundant equipment for the safety of plant personnel.[12]

The first experimental run had begun on May 18, 1961. The two years of experimental runs prepared the plant for its first hot run, or campaign, which began on December 23, 1963.

PART FIVE
THE FLUIDIZED-BED WASTE CALCINING PROCESS AND THE WASTE CALCINING FACILITY

The concept of fluidized bed technology was not new. It had been applied in the petroleum, iron and steel, and limestone industries. In fact, the term "calcination" originally applied to the process of heating limestone to drive off carbon dioxide from calcium carbonate, leaving a calcium powder.

As applied to liquid radioactive wastes at the WCF, the process involves placing a bed of sand-like granular material at the bottom of a cylindrical vessel--the calciner vessel. The grains are then heated to temperatures of 400 degrees C or more by a heat exchanger placed directly in the bed. A flow of hot air is introduced into the bed through fourteen holes at the bottom of the vessel and evenly distributed to the grains, placing the grains in motion, or "fluidizing" them. Liquid waste is fed as a fine mist into the vessel by pneumatic atomizing spray nozzles. In the hot environment, the water vaporizes and the solids adhere to the small starter grains tumbling around in the fluidized bed. As the process continues, the solids knock against each other, causing particles to flake off and form the starter grains for the continuously sprayed liquid feed. As the granular solid--called *alumina*--accumulates, it leaves the bed through an overflow pipe, from which it is transferred to storage bins by pneumatic processes. Water vapor, nitrogen oxide gases, fluidizing air, and other volatiles exit the calciner vessel along with the fluidizing air.

Unfortunately, one of the "other volatiles" is ruthenium-106, a radioactive element present in the liquid waste. The high heat of the calciner converts it to a gaseous form. Considerable portions of the calcination process must therefore be devoted to the control of ruthenium, since it is too dangerous to exhaust into the atmosphere through the stack. Additional "cleaning" of the off-gas required quenching, filtration, scrubbing, and separating the ruthenium-106. At the end of the process, the

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[12] Lakey, p. ii-5.

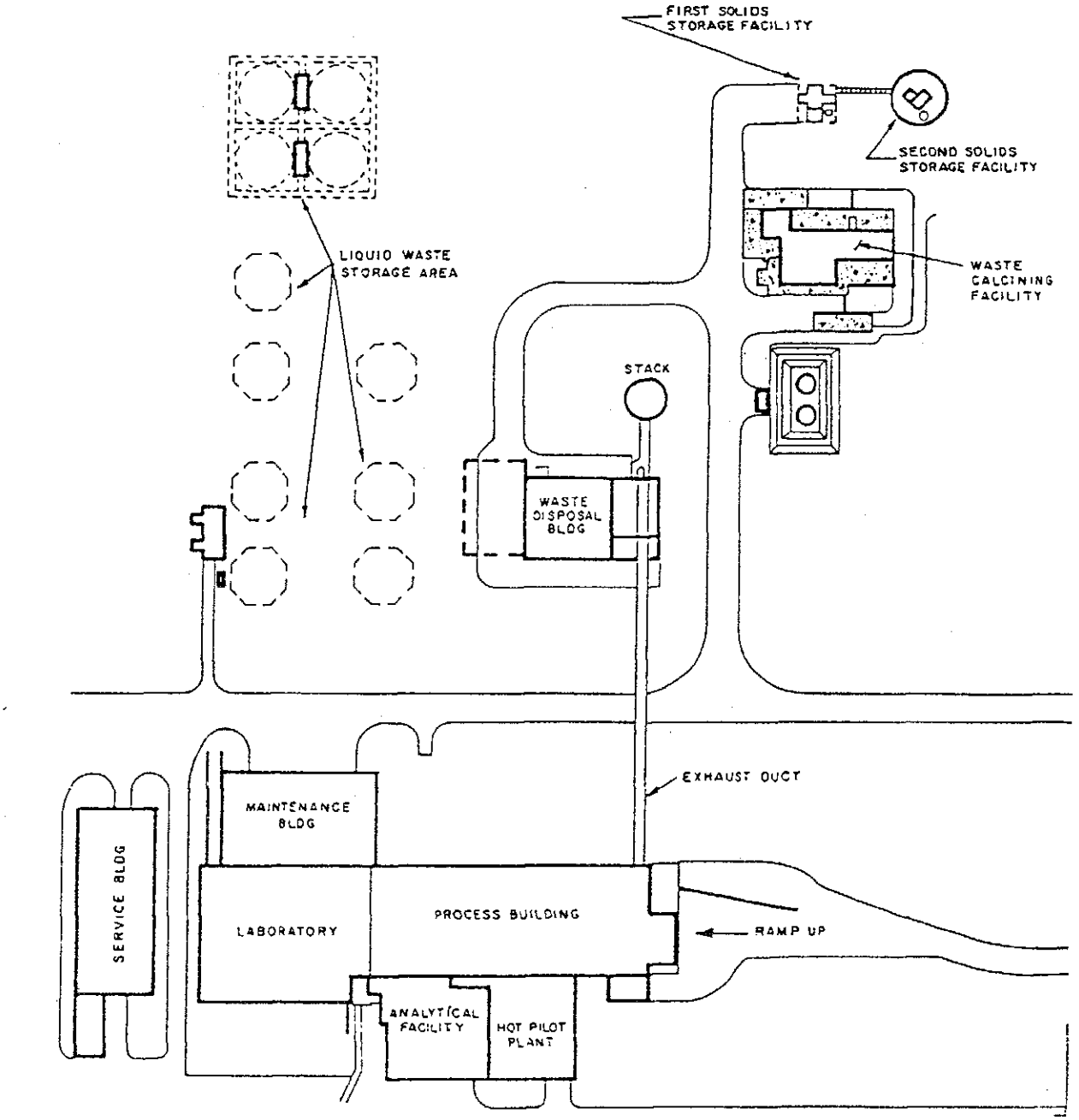

Fig. 2. Partial plot plan of the Chemical Processing Plant. Shows relationship between the WCF, the process building, liquid waste tanks, and the calcine (solids) storage area.

Source: Bendixsen, C.L., *Safety Analysis Report for the Conceptual In-Bed Combustion System for the Waste Calcining Facility* (Idaho Falls: Idaho Nuclear Corporation Report No. CI-1119), p. 5.

ruthenium adsorbed onto silica gel and joined the rest of the calcine for storage in heavily shielded metal bins near the WCF.[13] (See Appendix C for a more technical description of the waste calcining process.)

The over-riding imperative guiding the design of any process dealing with hazardous radioactive waste is to protect workers from danger. In executing this imperative, the calcining building followed two main principles that had been implemented earlier in CPP's Fuel Processing Complex (CPP-601). The first derived from the decision to clean and decontaminate by the direct method mentioned above. The second was that the radioactively hazardous areas, which consisted mostly of the process activity itself, were located below grade, while the non-radioactive service areas were on the ground floor.

The heart of the WCF building was the calciner vessel. Leading to it, elaborate piping systems fed it with heat, liquid waste, and hot fluidizing air. Leading away from it, the pipes carried away its products: off-gases went to the CPP stack; the calcine, to storage bins. The WCF building was built east of the Fuel Processing Complex (CPP-601) and south of the tank farm. Within its footprint of 110 feet by 70 feet, the building contained everything required for the calcining process except for the tanks that stored fuel oil and the bins that would store the calcined product. From the outside, the building appears to be in three sections, each with a different roof elevation. The outside of the building is best understood by considering the chemical processes that took place within.

The above-grade portion of the building was built of hollow-core pumice blocks, while the basement was built of heavily reinforced concrete. The sub-grade processing cells were arranged in two parallel banks with a shielded corridor between them. Lining the walls of this corridor were operation control panels, monitors, and switches, at which personnel stood to operate the facility.

For maintenance during shutdown periods, crews used remotely controlled cleansing sprays to flush each operating cell. Equipment pertinent to the operation of each cell was located just outside the cell, typically encased in shielded lead or steel cubicles. Crews used ladders, platforms, and removable

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[13] D.R. Evans, p. 3. See also Robert D. Thompson, Ruthenium Behavior during Fluidized Bed Calcination of Radioactive Waste Solutions: Problem Review and Program Suggestions (Idaho Falls: Phillips Petroleum Company Report No. PTR-743, 1965).

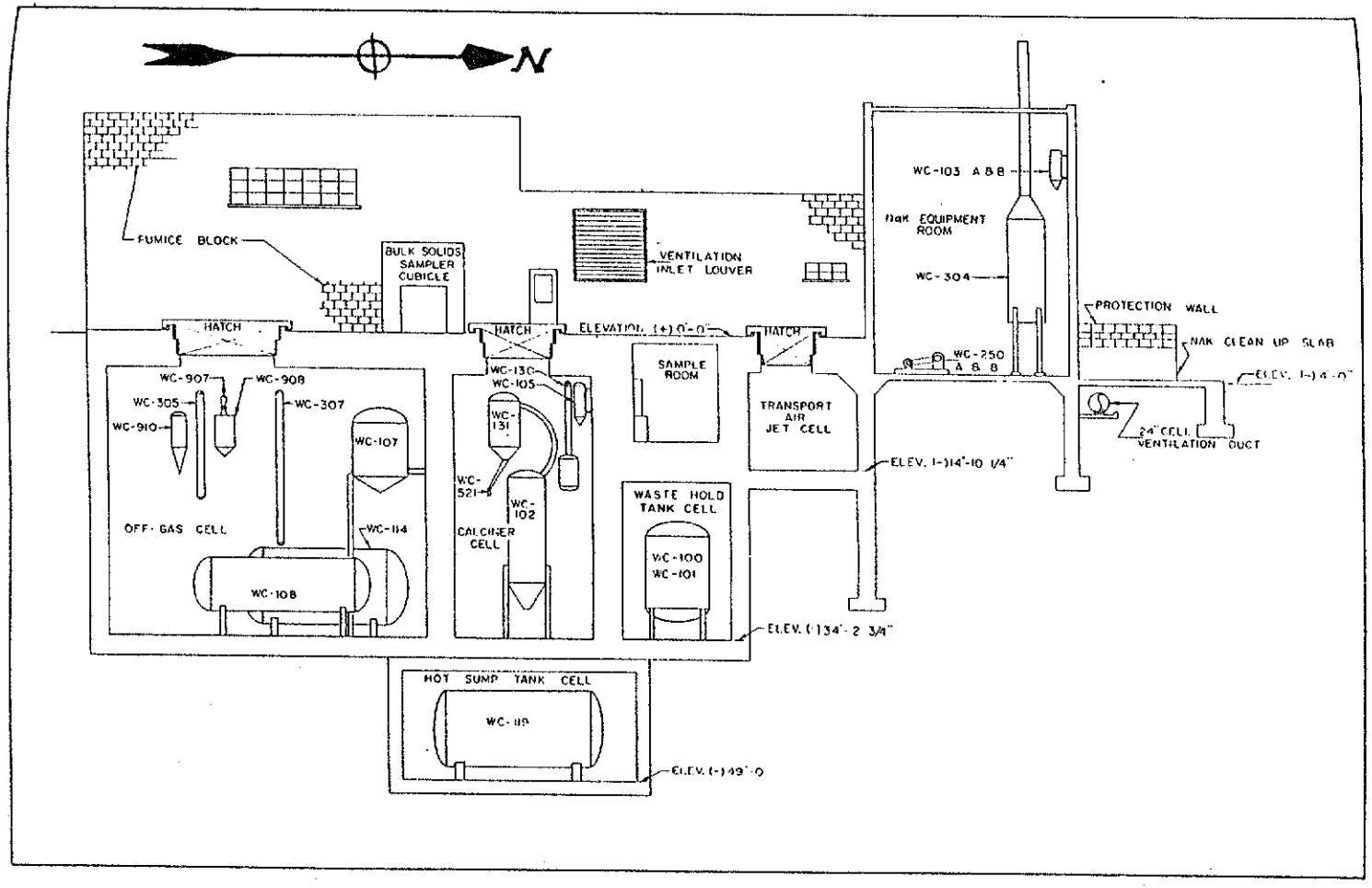


Fig. 3. Elevation of east side of the WCF

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report* (Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

hatches to gain access to the equipment. Most equipment was made of stainless steel to resist the corrosive attacks of decontaminating solutions and the acids of the radioactive feed itself. Interior surfaces of walls and cells were covered with a variety of coatings depending on the severity of contamination expected--stainless steel sheet, radiation-resistant paint, asphalt tiles, or flat wall paint.

The steel calciner vessel was four feet in diameter and eighteen feet high; it stood in a shielded cell below grade. Originally, its source of heat was a loop of NaK (sodium-potassium eutectic alloy). Heated by an oil-fired furnace, the NaK circulated at temperatures up to 760 degrees C. Several other vessels were part of the process, needed for mixing, sorting, or other activity. Each was isolated in a concrete-shielded cell.

Main Floor Level

The main floor level was built four feet above grade. It contained five rooms. Because the rooms overlay the various hot cells, the floors were made of sufficient concrete (at least three feet thick) to shield personnel from the hazard below. Walls and room dividers were of structural steel and pumice blocks. A Health and Safety Office included a small shielded cubicle for sampling the gases that were leaving the building. A Switch Gear Room contained the electrical power controls for the facility. A Locker Room for personnel contained bathrooms and hand and foot counters (to detect radiation). These rooms occupied the center section of the building and had the lowest ceiling, which was about eleven feet high.

The Decontamination Room contained tanks filled with chemicals. These made up the solutions added to the waste feed or that flushed the operating cells after a campaign. A hopper containing the calciner start-up material also was located here, along with compressed air equipment, steam manifolds, and solution-transfer pumps. This room was situated above the operating corridor. Piping for the transport of each of the chemical solutions led from their containers through the floor down behind the operating panels in the corridor below. The tall narrow tanks in this room required a ceiling height of 27 feet. (See Photo HAER No. ID-33-C-9 for a view of this room.) From the outside, this high-bay section of the building is readily apparent as the south anchor of the WCF.

The fifth room was the Heating and Ventilating Room. Outside air entered the supply unit, was filtered, heated, washed, and reheated before it was sent to the rest of the main floor or to the operating areas below.

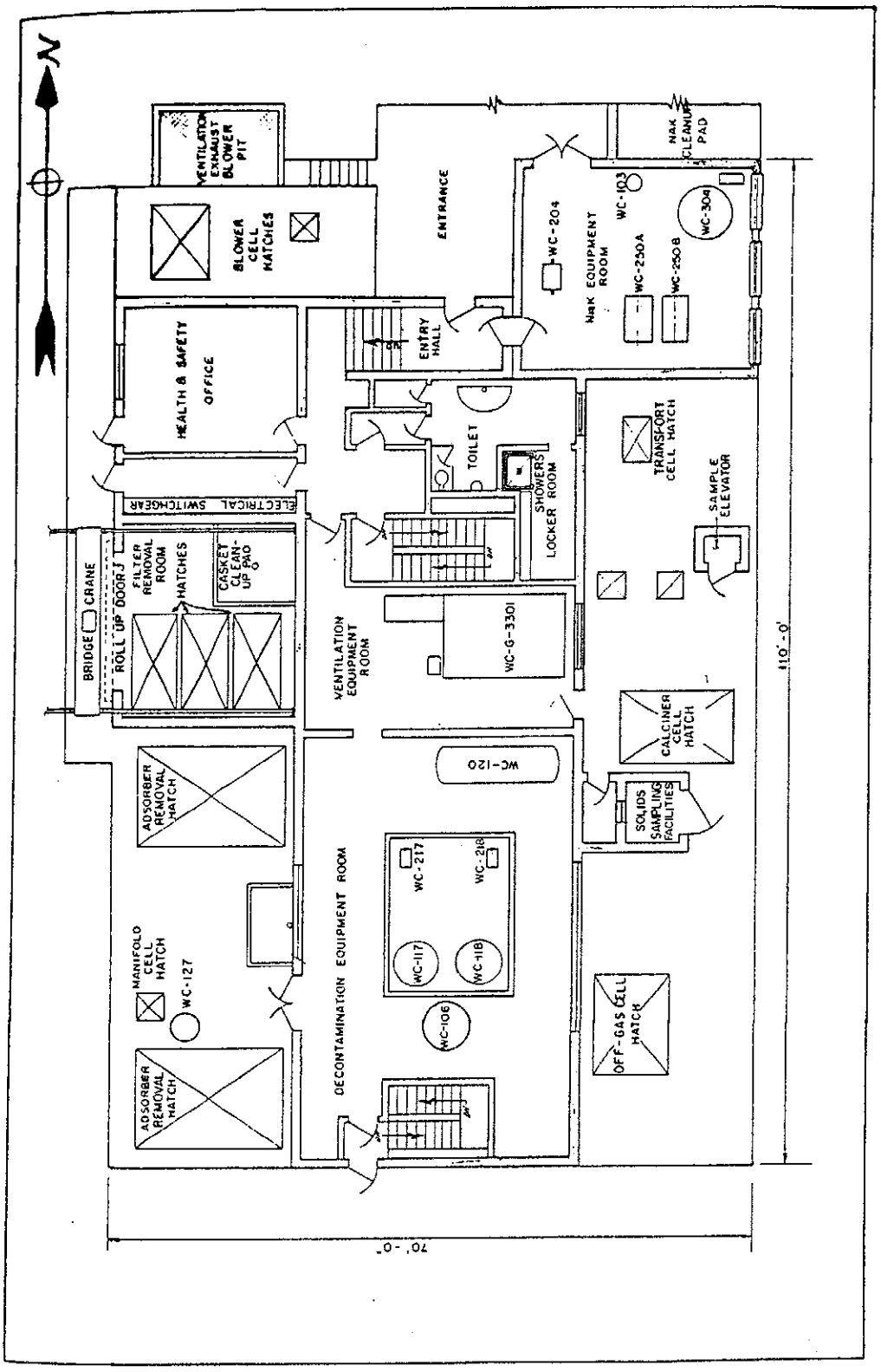


Fig. 4. Plan view of the main floor level of the WCF

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

NaK Handling Level

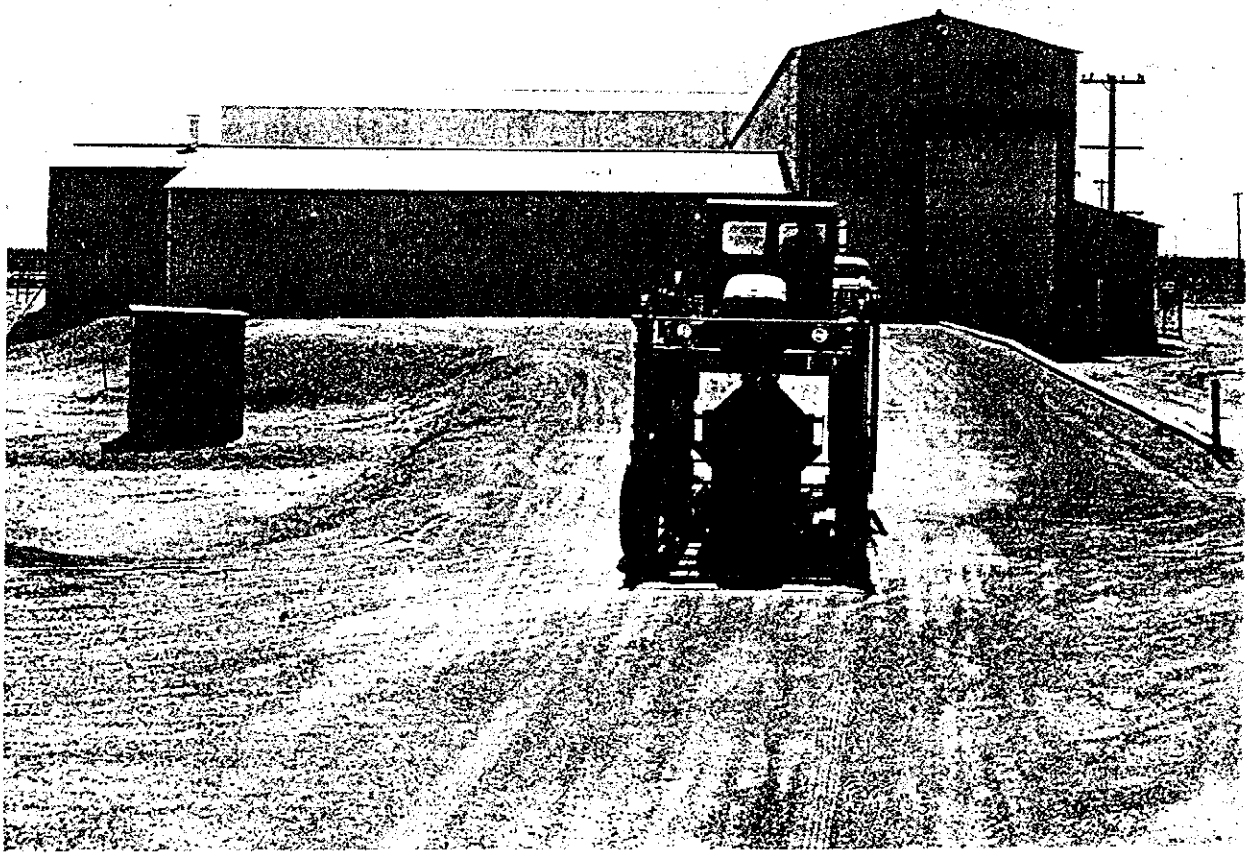
A special equipment room for handling NaK was located three and a half feet below the main floor and just above grade level. NaK reacts violently in the presence of air and moisture, forming hydroxides that burn living tissue (and other material) and are otherwise corrosive and irritating. Its lower-level position functioned somewhat as a pit in relation to the main floor. It prevented leakage into the other rooms or cells of the building. In fact, this room was actually a separate building connected to the main level by a hallway, but sealed by two doors. The room contained the NaK furnace, tanks, fluidizing air blowers, pumps, indicators, and a helium manifold system. To accommodate the furnace, its ceiling was 30 feet high. This room was the north anchor of the building. The furnace chimney protruded several feet above the roof.

A Filter Removal Room was approximately at grade level also. Off-gases from the calciner were passed through filters to remove fine radioactive and other particles. The filters were in three cells just below the Filter Removal Room and, when spent, had to be replaced with fresh filter units. Operators worked outside this room and managed the filter-replacement procedure remotely. They stood in the filter-removal corridor behind a shielded glass viewing window (40 inches thick) to operate the crane and other equipment. A 20-ton bridge crane lifted the four-foot thick concrete cell covers, helped place the spent filters in special shielded transport casks, and then placed the casks for pick-up by "straddle carriers." The carriers took them to a waste storage facility elsewhere at NRTS. The crane extended 20 feet from the building. (See Photo HAER No. ID-33-C-3 or ID-33-C-8.) These views of the west side of the WCF also show the entrance to the Filter Removal Room, which was via an exterior roll-up door.

Operating Corridor Level

Below grade, process activity occurred at several elevations. One level contained the Operating Corridor, reached by a stairway from the main floor. The corridor was parallel to the north-south orientation of the building, 15 feet wide and about 77 feet long. The main instrument panel was centered here, while service piping for the cells was located along the sides, making for convenient access. Another function at this level was a Sample Room, where operators could collect a sample either of the liquid waste or the solid calcine and place it in a container called a "pig" and send it on an elevator to the main floor for transport to a hot cell or laboratory for further examination and analysis.

A cell next to the Sample Room contained air jet equipment used to move the granular calcine to storage bins located outside of the WCF. Other cells at this level included the Off-gas Blower



Straddle carrier truck transports a cask of spent fuel elements. In the background building, fuel was stored until ready for chemical reprocessing.

Source: Phillips Petroleum Company, *Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho* (Idaho Falls: PPCo, no date), p. 30.

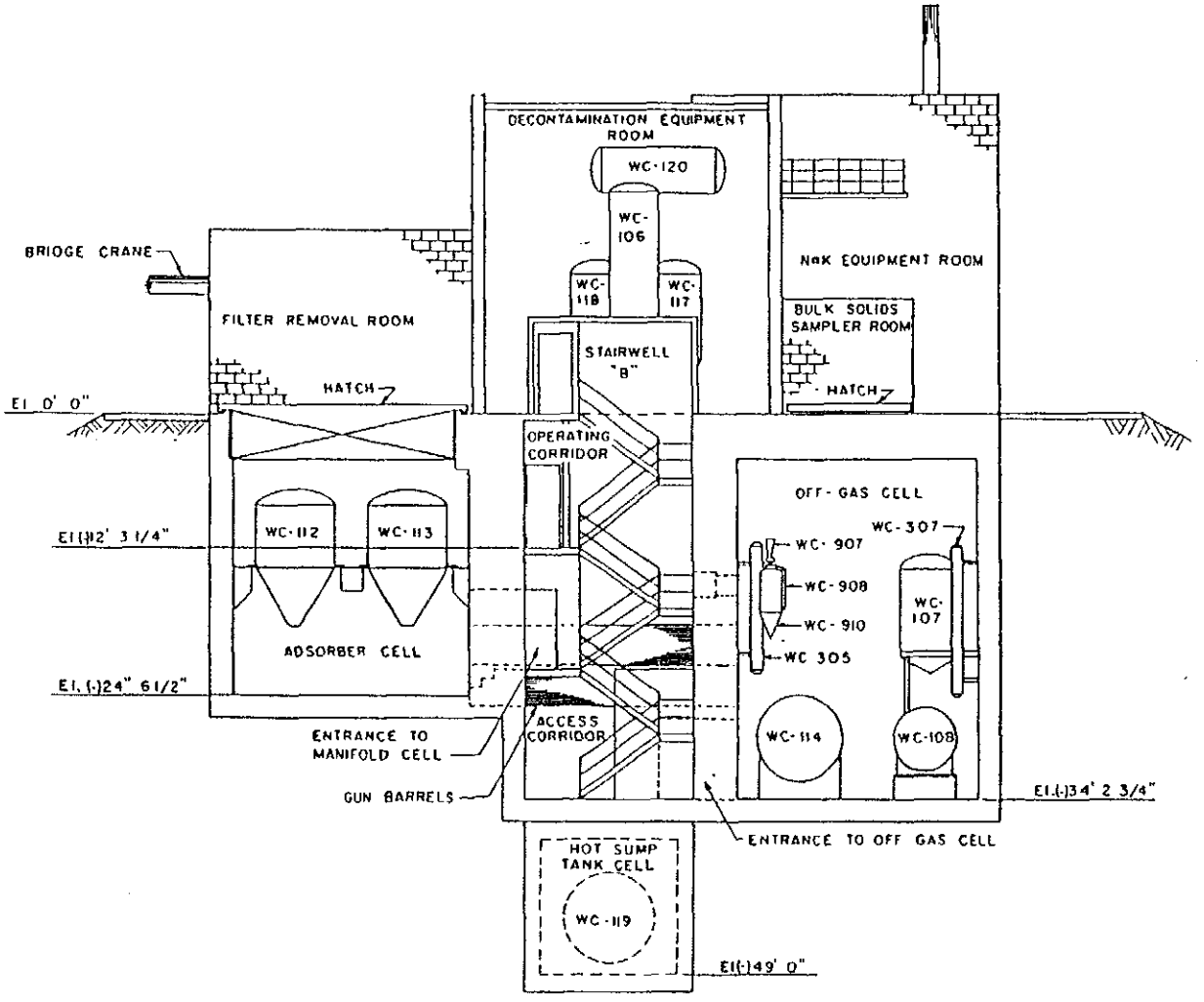


Fig. 5. Elevation of south end of the WCF. Shows relationship between operating and access corridor levels.

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

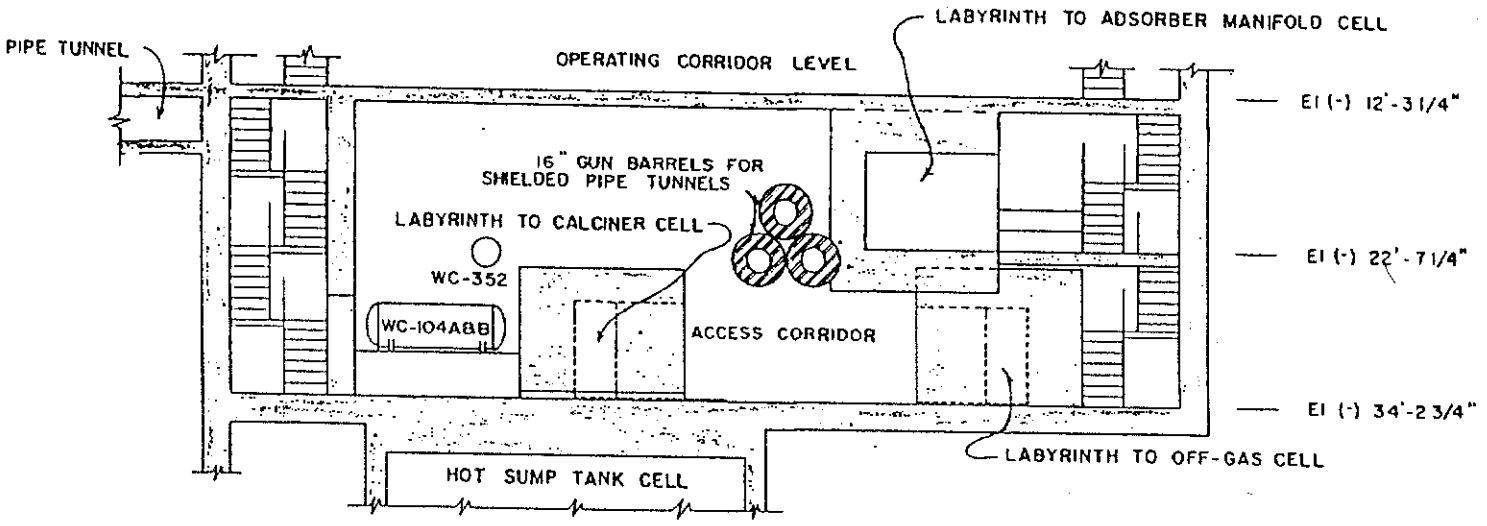


Fig. 6. Elevation of west side of Access Corridor shows position of three gun barrels beneath floor of Operating Corridor.

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

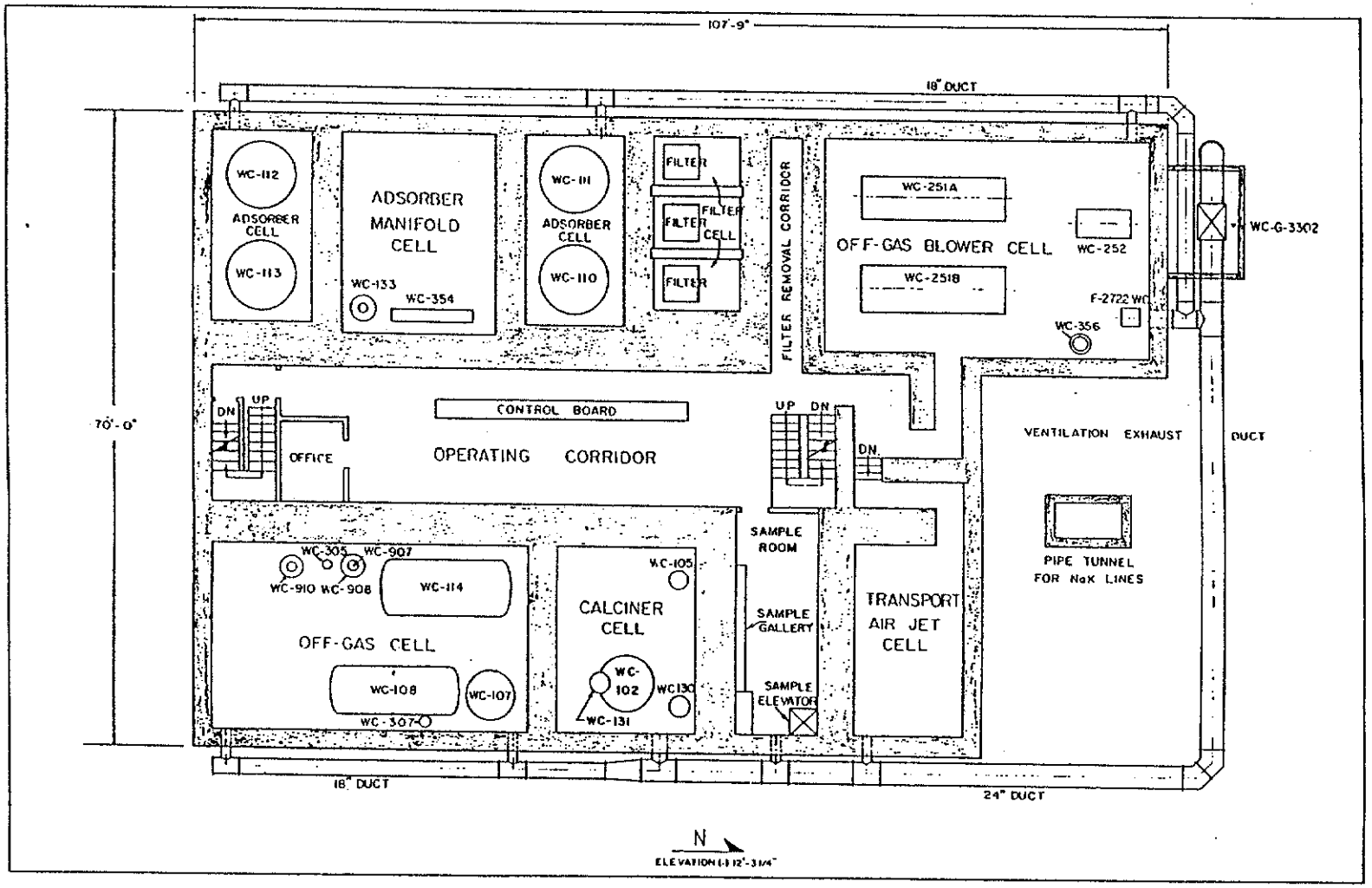


Fig. 7: Plan view of Operating Corridor. Note "labyrinth" concrete construction at entry to off-gas blower and transport air jet cells.

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

Cell, a small Filter Removal Corridor, the cells containing the air filters, and a Blower Pit. The blower maintained a positive flow of air from the non-radioactive areas to the hot cells and then to the stack.

Access Corridor

This corridor provided access to the process cells and related equipment located directly below the operating corridor. On each side were the hot process cells. Technicians could access the calciner and other cells by going through a "labyrinth," a maze-like arrangement of concrete shields.[14] Three of the process pipes crossed the access corridor. To shield operators in the corridor, the pipes were placed in tunnels made from surplus 16-inch U.S. Navy gun barrels, left-overs from World War II days when the Navy had used the NRTS site to re-line and proof them. Fluor had scrounged them during construction. (See Photos HAER No. ID-33-C-16 and ID-33-C-18.)

A Waste Hold Tank Cell was at the east end of the corridor. The tanks held the liquid waste solutions awaiting feed into the calciner. The solutions, including spent decontamination chemicals, rested here until the next campaign, when they became part of the feed into the calciner.

Next to this was the large Calciner Cell, which contained the calciner vessel, the NaK heat exchanger, the calciner cyclone, feed metering pot, and other related eguipment. Maintenance technicians entered this cell through a shielding labyrinth.

Next to the Calciner Cell, the Off-gas Cell contained quenching tanks, pumps, venturi scrubbers, and other equipment related to the handling of the gases that left the calciner. Other cells included a Hot Sump Tank Cell (situated beneath the access corridor floor), Adsorber Manifold Cell, two Adsorber Cells for ruthenium-106, and a Filter Piping Tunnel.[15]

Several utility systems served the WCF. Electrical power, from both the general NRTS system and CPP's emergency diesel generator, was available via buried power lines. A raw water system supplied domestic and fire suppression needs within the building. A fire hydrant is visible in Photo HAER No. ID-33-C-6.

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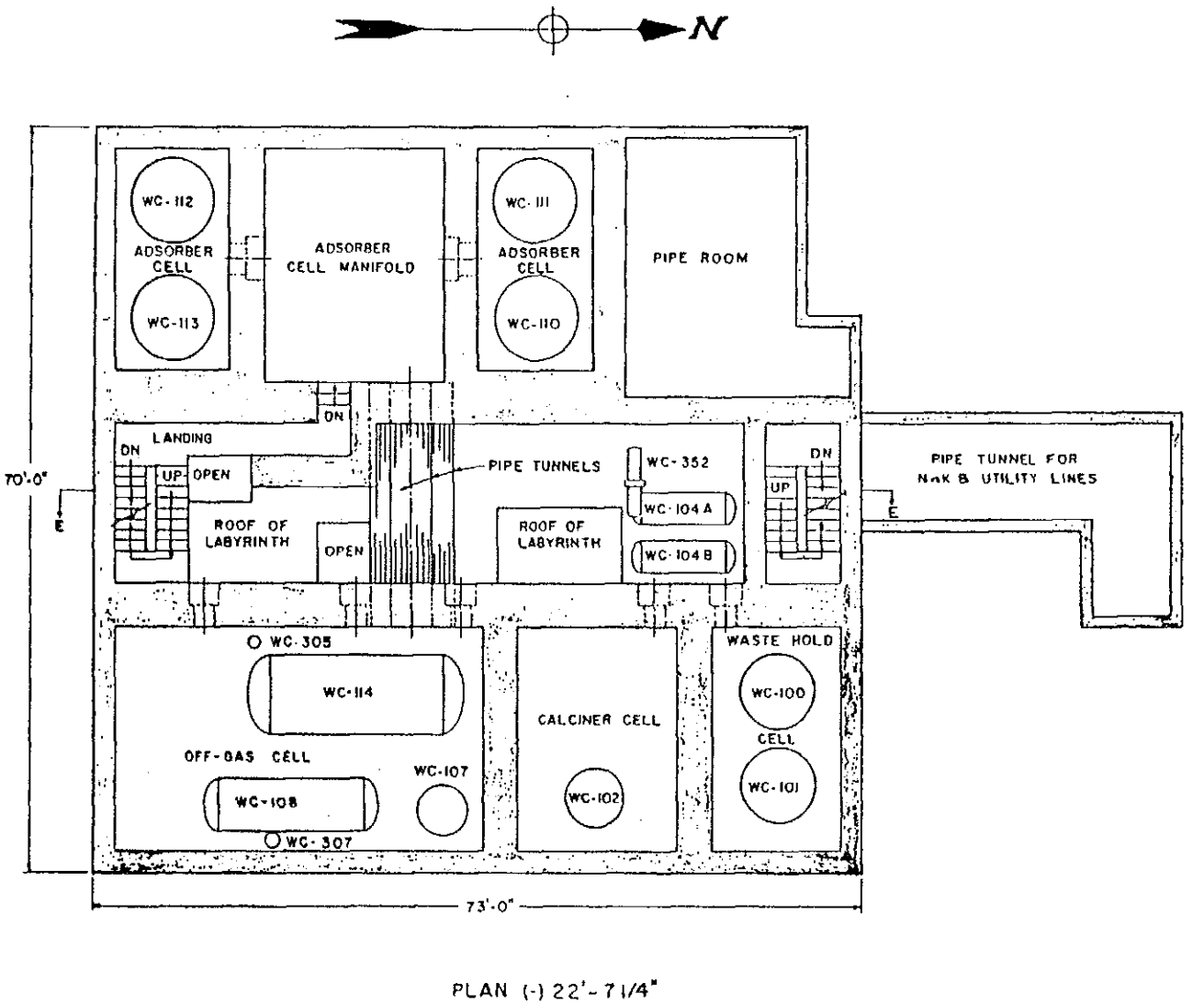
[14] Radiation proceeds in a straight line from its source, as opposed to turning corners. "Labyrinth" construction is designed to block its progress.

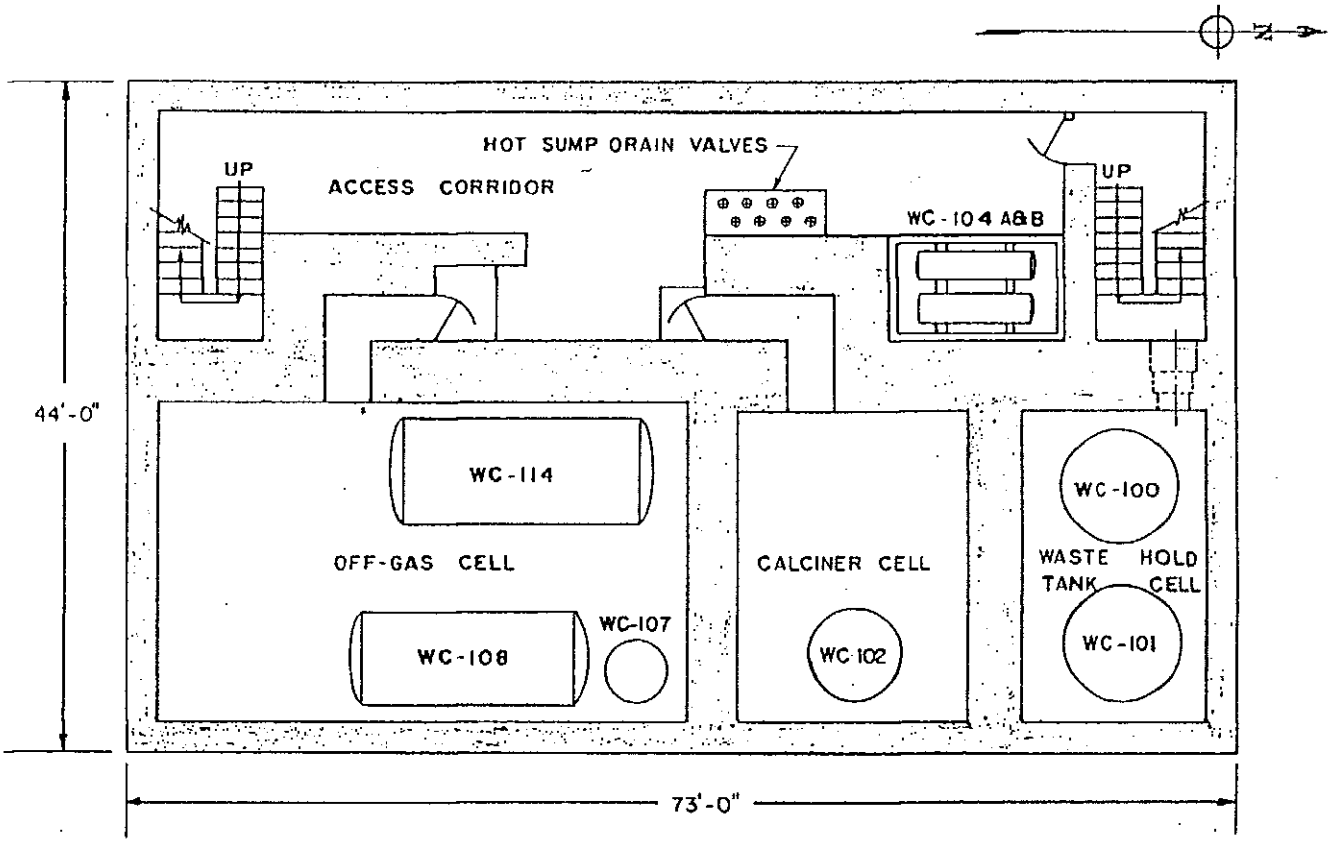
[15] Description of each room and cell can be found in further detail in Lakey et al, Safety Analysis Report, cited in Note 11.



PLAN (-) 22'-7 1/4"

Fig. 8: Plan view of the Access Corridor (High) Level

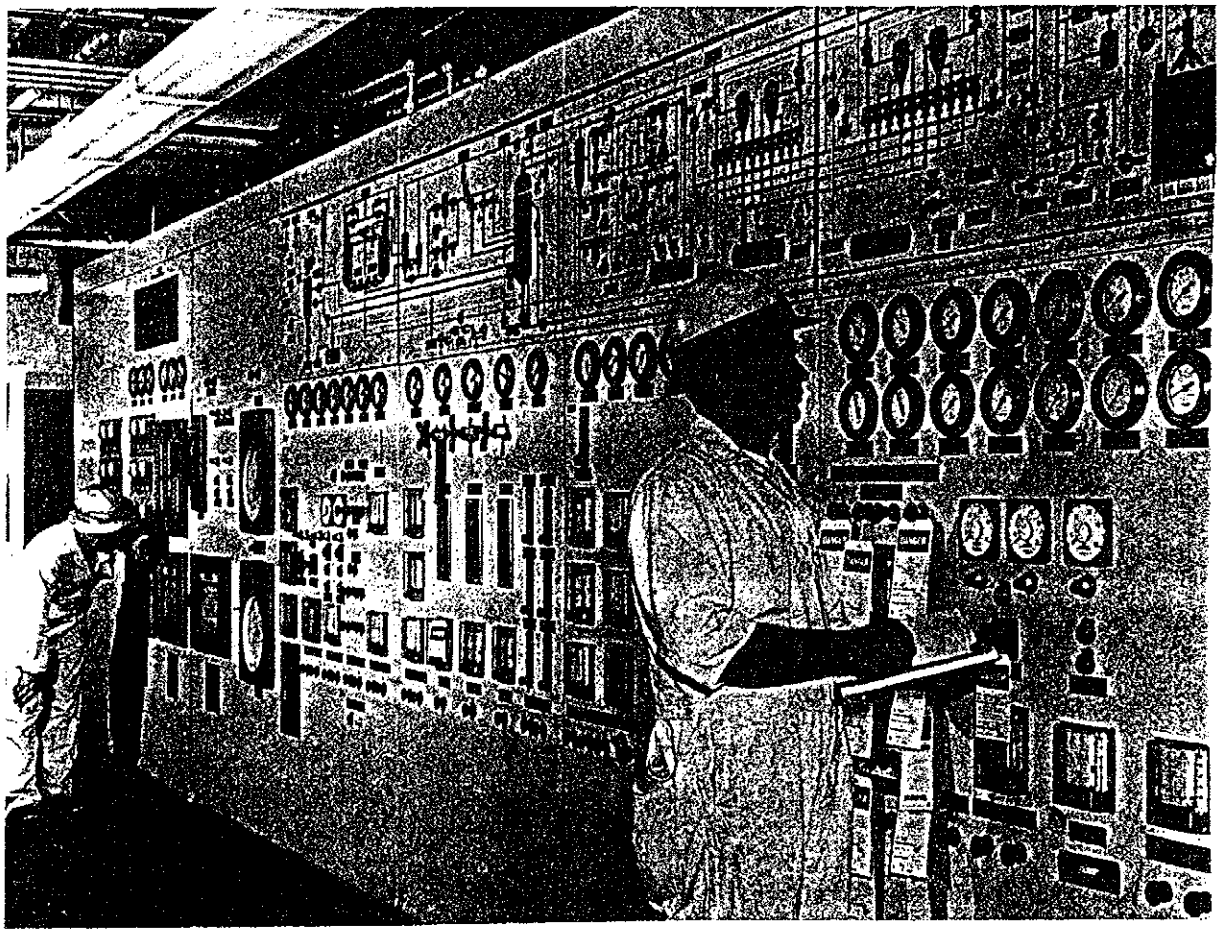
Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.



ELEVATION (-) 34'-2 3/4"

Fig. 9: Plan view of the Access Corridor (Low) Level

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.



Control panel of the WCF located on Operating Corridor Level

Source: Phillips Petroleum Company, *Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho* (Idaho Falls: PPCo, no date), p. 24.

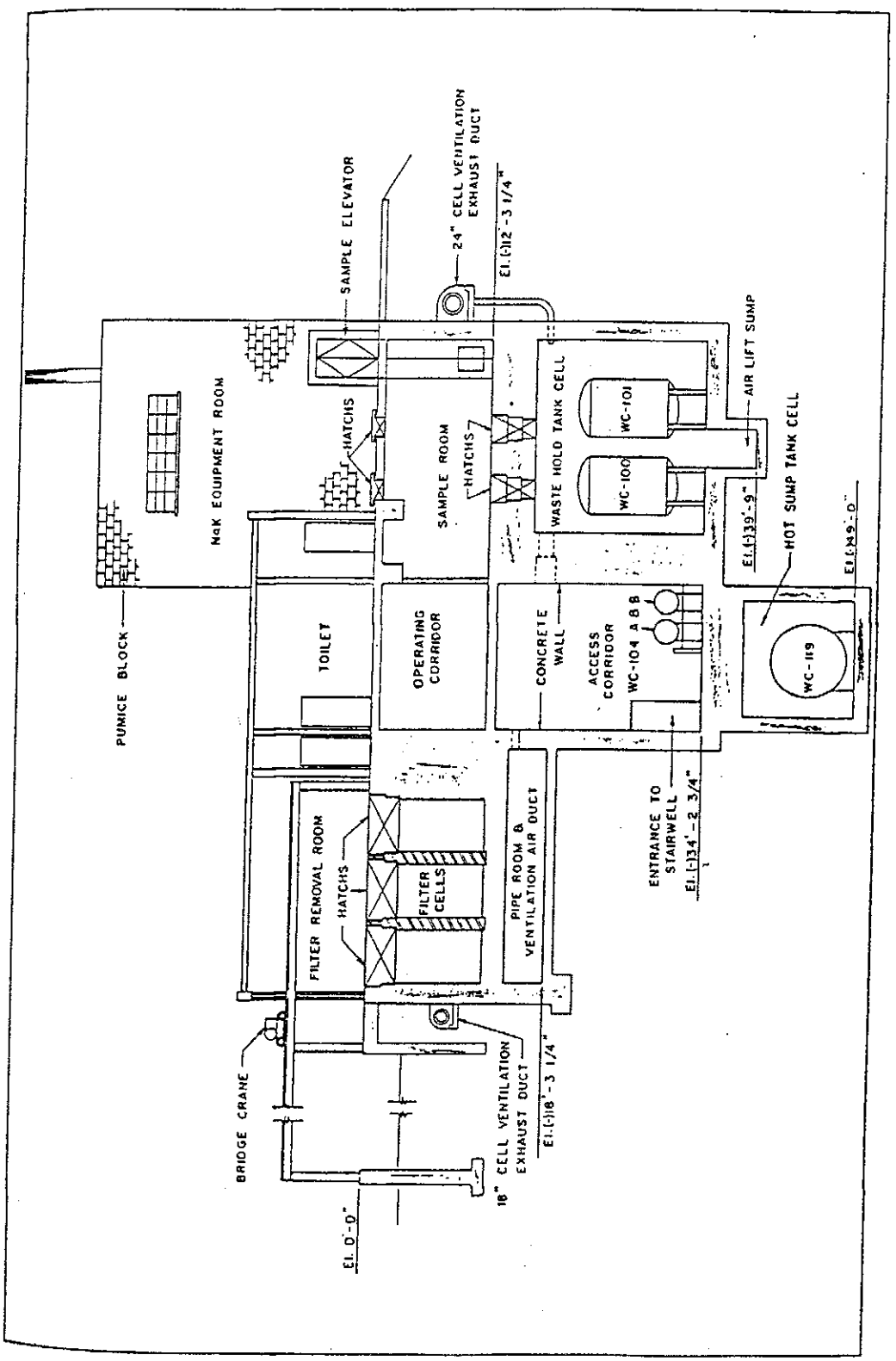


Fig. 10: Elevation of the south end of the WCF. Note bridge crane and filter removal room on left side of view.

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

Compressed air from a central CPP service building (CPP-606) served process and instrumentation needs of the WCF. The utility piping was buried underground. A service waste system drained condensate from heating and ventilating systems to a collection tank equipped with pumps and an electric motor. For personnel safety, the heating and ventilating system moved air from the operating areas toward the process cells. Sanitary waste went to CPP's central disposal system near the CPP north perimeter fence.

From the outside, each face of the building presents a unique appearance because of the three different roof elevations and special features that protrude from the walls, although all sections have flat roofs and are constructed of unpainted hollow-core block walls. The west elevation presented the bridge crane and roll-up door required to remove the contaminated air filters. This side also has doors into the Health Physics and Locker Room area and windows for natural light. The Decontamination Room on the south end contained a ribbon of windows located in the upper portion of the wall. Two concrete pilasters conceal steel framework members. Piping and small tanks were affixed to the exterior walls. (See Photo HAER No. ID-33-C-4.)

The south elevation consists of the end of the cube-shaped Decontamination Room. It has a door, no windows, and one vertical pilaster. Piping and conduit pierce the wall in several places.

The east elevation, against which a low earthen berm can still be seen in Photo HAER No. ID-33-C-4, includes a concrete pad outside in front of the Decontamination Room. On this pad were several concrete hatches that provided access to the cells below--the Off-gas Cell, Calciner Cell, and others. On the upper level of the Decontamination Room wall, was another ribbon of windows similar to those on the west side. The Sampling Room, used by the health physicists, was a small cubical structure projecting from the side of the building between the two largest hatches. It had an access door for personnel and an opening to facilitate the transfer of samples. A personnel door provided access to the rooms on the Main level. Above it to the right was a ventilation inlet louver. In Photo HAER No. ID-33-C-5 this louver is concealed by the demolition contractor's covering. Another metal roll-up door provided access for deliveries of make-up chemicals to the NaK Handling Room.

The NaK Handling Room dominates the northeast end of the building. Ventilation and combustion air for the furnace enter the room from three adjustable louvered windows located on the east wall. (See Photo HAER No. ID-33-C-5.) Moving around the building to look squarely at the north end of it, one observes a concrete pad and a double door for access to the NaK Handling Room. A protection wall made of hollow-core blocks projects from

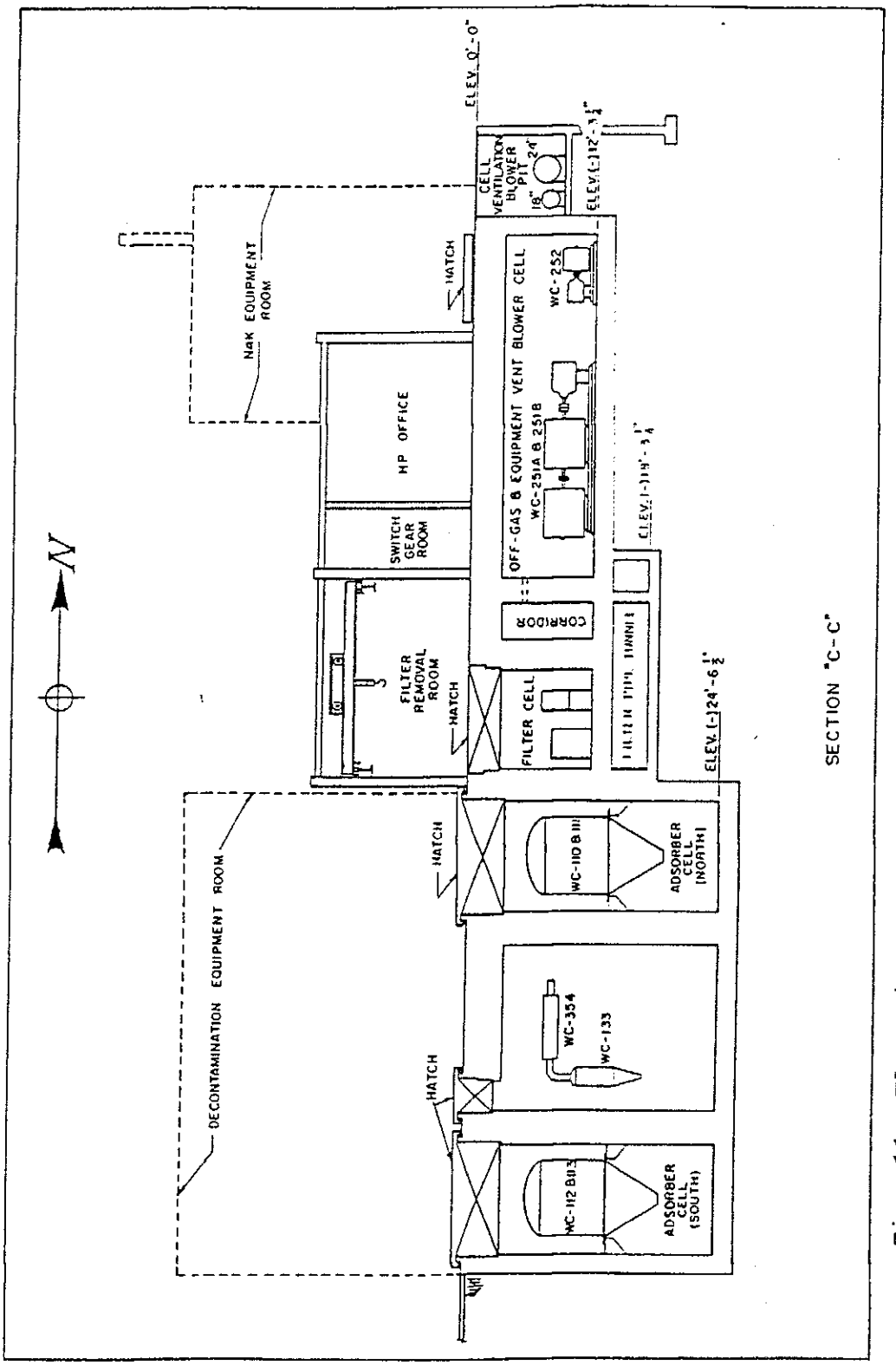


Fig. 11: Elevation of the east side of the WCF. Hatches indicate presence of subsurface vessels. Access was from exterior of the building.

Source: Lakey and Brower, *ICPP Waste Calcining Facility Safety Analysis Report*) Idaho Falls: Phillips Petroleum Company, US AEC Report IDO-14620, 1963), chapter iv.

the north wall of the NaK room. This wall is visible (in shadow) at the right side of Photo HAER No. ID-33-C-5 and just to the left of the double door in Photo HAER No. ID-33-C-6. The bricks were arranged to provide four see-through spaces near the top of the wall. The wall protected the doorway in the event of a NaK spill. Further west is another concrete pad upon which sit more large hatch covers, these to the Blower Cell. In Photo HAER No. ID-33-C-6, a tent-like cover sits above the Ventilation Exhaust Blower Pit. Also visible is Building CPP-667, erected in 1961, which was used infrequently as a supplemental office area for the WCF. It blocks the view of the north doorway into the WCF.

Other buildings that were part of WCF operations include a fuel oil storage structure, situated just west of the WCF building, where fuel for the NaK furnace was stored. East of the WCF are the calcine storage bins.

The calcine was stored--and continues to be stored--in seven "bin sets" located about 100 feet east of the WCF. The first was built in 1963. When the WCF began its hot operations, the plan was to begin processing the oldest wastes first, those which had been cooling for at least two years. Therefore, the first bins were designed with lighter shielding than the storage bins that came later. The bin set design accounted for possible future decisions to move or further process the calcine. Each has the necessary lines and suction nozzles to allow for retrieval.[16]

A bin set is a group of four to seven tall, narrow steel bins erected in a reinforced concrete vault. (The bins in the second bin set are twelve feet in diameter and forty-two feet high.) Calcine arrives at the bin set in one feed line, where it is distributed to the vertically positioned bins. They stand partly above grade level, their concrete vaults surrounded by earth and gravel shielding. The whole affair resembles a barren hill with small buildings on the top. Heat from radioactive constituents in the calcine is carried off by air circulating past the bins. That air and the air used to move the calcine to the bins returns to the WCF for treatment along with the rest of the calciner off-gas. The shielding, cooling apparatus, off-gas cleanup equipment, and control housings for Bin Set No. 2 are visible at the right side of Photo HAER No. ID-33-C-1.[17]

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[16] J.A. Hendricks and A.G. Westra, A Prototype Facility to Demonstrate Retrieval and Storage of Simulated ICPP Calcined Waste (Idaho Falls: Exxon Nuclear Idaho Company, US DOE Report ENICO-1093, 1981), p. 1.

[17] For a simplified sketch of the first bin set, see L.T. Lakey, et al, IDO-14608, p. 25.

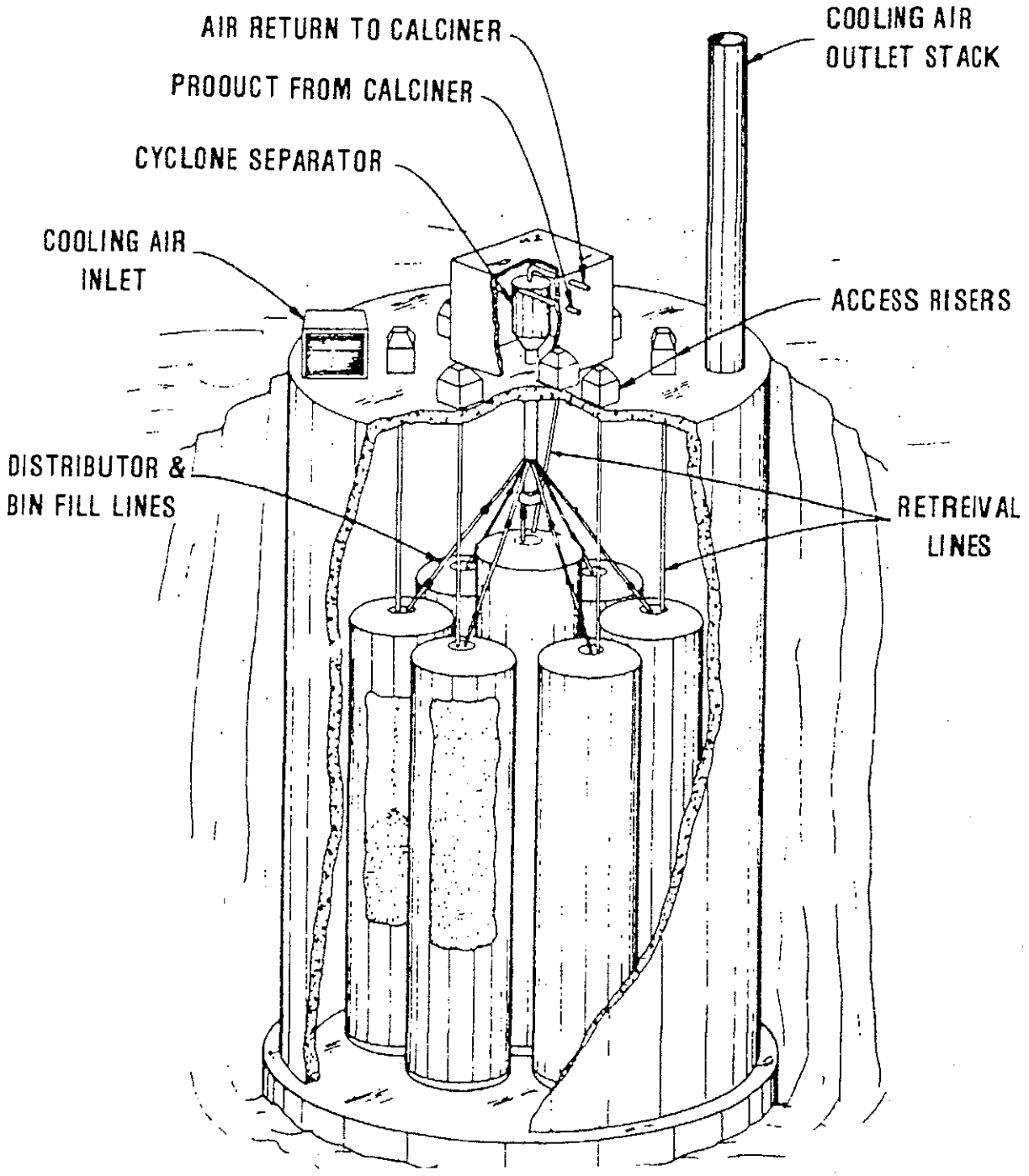

Fig. 12: Sketch of a "bin set," a storage facility for the calcined solids. See Appendix C for description of fill process.

Source: Hendricks and Westra, *A Prototype Facility to Demonstrate Retrieval and Storage of Simulated ICPP Calcined Waste* (Idaho Falls: Exxon Nuclear Idaho Company, US DOE Report ENICO-1093, 1981), p. 2.

PART SIX
THE WASTE CALCINING CAMPAIGNS

A campaign was a continuous run--or as continuous a run as possible considering equipment breakdowns or power outages--of a quantity of liquid waste through the calciner. The first campaign lasted ten months, from December 1963 to October 1964. During this time, the waste feed stopped for only 56 hours (51 of them due to NaK leaks in the non-radioactive part of the facility). The campaign ended when the available storage bins filled up.

The WCF had taken half a million gallons of liquid waste from three different tanks, emptying two of them, and converted it to 7,500 bulk cubic feet of alumina--and it had done so at a rate 15 percent greater than the design rate of 60 gallons per hour. The reduction in volume was over 9 to 1. Neither equipment nor feed lines had plugged up; rotating equipment had performed perfectly; and remote lubricating systems had worked so well that no spares were called into service. The alumina traveled without incident from the calciner to the storage bins, despite several bends in the system. Release rates into the atmosphere of strontium-90 (particulates) and ruthenium-106 were substantially below guidelines. Analysts who had forecasted such matters as particle size and other properties of the calcine solid were gratified to find that performance matched prediction. The author of one report on the campaign credited these excellent results to the skill of the operating crew, which had learned its work operating ten test runs the previous two years.[18]

The Waste Calcining Facility became the world's first production-scale plant to convert high level aqueous waste to a solid form--and it was an unambiguous success. The decision to continue operating was not hard to make. It was time to build new bin sets, and the "demonstration" plant soon became a regular production plant, working routinely for the next eighteen years.

The second bin set was ready for action in 1966. The second campaign began April 1, 1966, and continued for two years until March 24, 1968. This run accomplished another landmark for the WCF. It calcined wastes with a substantially different chemical

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[18] R.E. Commander, et al, Operation of the Waste Calcining Facility with Highly Radioactive Aqueous Waste (Idaho Falls: Phillips Petroleum Company Report No. IDO-14662, June 1966), p.1-4; and L.T. Lakey, et al, Development of Fluidized Bed Calcination of Aluminum Nitrate Wastes in the Waste Calcining Facility (Idaho Falls: Phillips Petroleum Company Report No. IDO-14608, May 1965), p. iii. IDO-14608 contains a summary of test-runs.

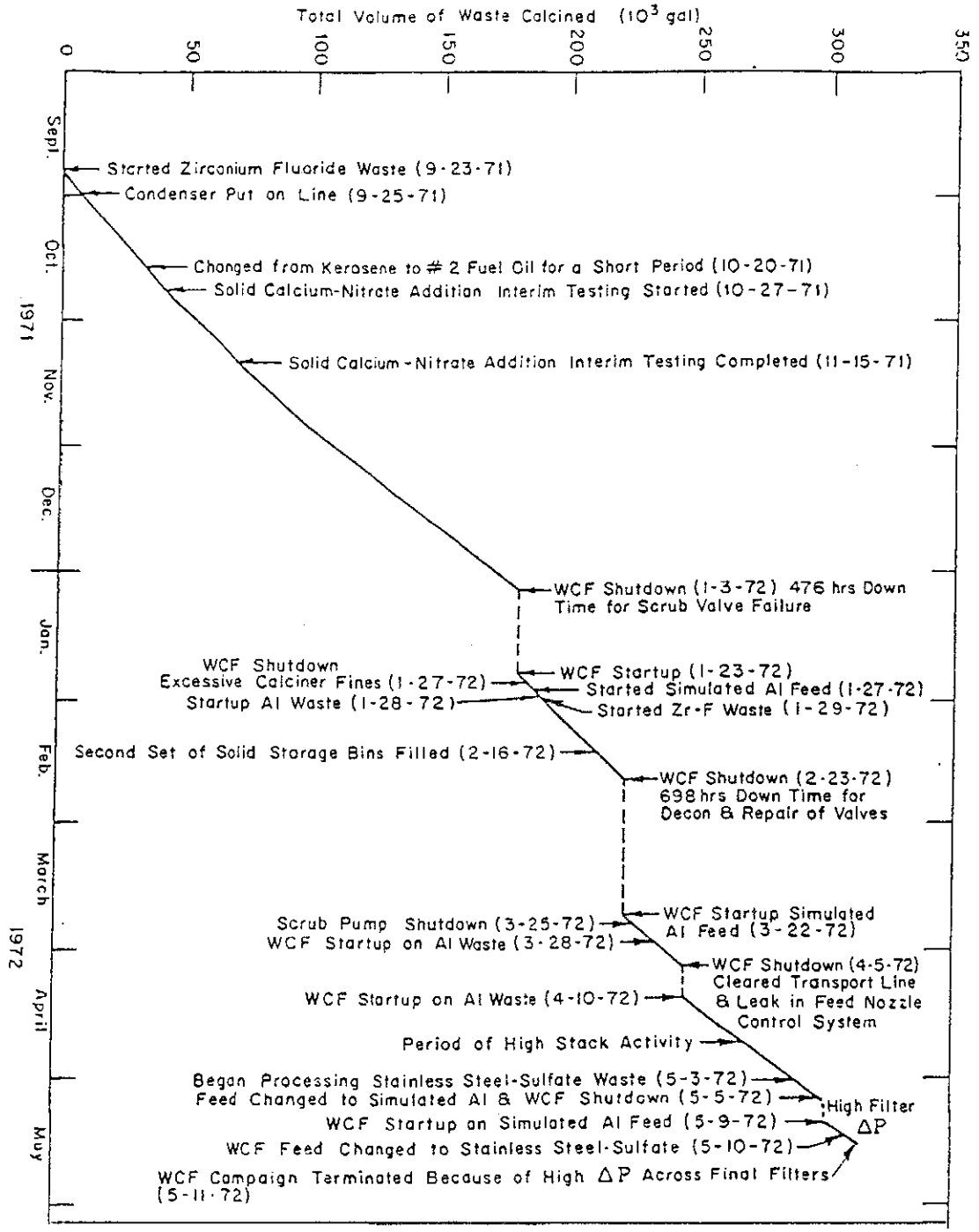

Fig. 13: Diagram shows the run and down times in the progress of a calcining campaign, this one the fifth. It began with Zirconium Fluoride waste and later included blends with Aluminum and Stainless Steel-Sulfate wastes. Second bin set filled on 2-16-72.

Source: Wielang, J.A. *The Fifth Processing Campaign in the Waste Calcining Facility, FY-1972* (Idaho Falls: Allied Chemical Corporation Report No. ICP-1021, March 1972), p. 3.

composition from the aluminum nitrate waste of the first run. Part of the feed contained zirconium fluoride, a very corrosive substance derived from spent fuel elements clad in zirconium rather than aluminum. WCF operators began learning how to "blend" wastes of different kinds for optimum performance.

Campaigns continued. After each one, the crews set about decontaminating the cells so that equipment could be inspected and serviced. Automated sprays and steam jets flushed out the cells first, but then the technicians--suited-up and masked--raised the hatches and descended into the cells to finish the job, replace worn parts, and make repairs. As the facility aged, post-campaign reports grew less and less enthusiastic about how easy or how safe the hands-on maintenance was getting to be. Ruthenium, for example, began to plate out on the interior of the off-gas process vessels. It resisted the internal sprays and exposed workers to hazard as they tried to remove it manually. Likewise, some of the vessels became scratched and pitted due to the corrosive effects of heat and solution.[19]

Meanwhile, the growth of the nuclear power industry went into full swing in the 1960s and 1970s. Fuel elements for commercial reactors began to come in a wider variety of cladding. Each new type presented new chemical challenges, first to reprocess the fuel and then to calcine it. The fifth campaign dealt successfully with stainless steel-sulfate solutions, transforming 5,000 gallons to 5,000 cubic feet of solid.[20]

The growing demand for reprocessing and calcining forced a change in how CPP managed its personnel. Up until 1973, the same crew operated the Fuel Processing Complex (CPP-601) and the WCF. Each facility alternated being "on" and "off," which gave adequate time for proper maintenance of the standby, or "off," facility. (In an interview, a former supervisor of the WCF observed that separate crews had operated the two complexes in the earliest days of the calciner's operation.) By 1973 demand was so great that the two facilities had to operate simultaneously. Design studies also began that year for a new, bigger waste calcining facility.[21]

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[19]J.A. Wielang, The Fifth Processing Campaign in the Waste Calcining Facility, FY-1972 (Idaho Falls: Allied Chemical Corporation Report No. ICP-1021, March 1972), p. iii.

[20]Wielang, The Fifth Processing Campaign, p. iii.

[21]Allied Chemical, The Waste Calcining Facility, Idaho Chemical Processing Plant (Idaho Falls: Allied Chemical Corporation, 1974), p. 2. For an operating summary of the first

PART SEVEN
THE WCF GETS A NEW SOURCE OF HEAT

The NaK heating system proved to be a troublesome method of applying heat to the calciner. Leaks in NaK flow lines reduced the operating efficiency of the WCF and presented substantial hazard potential. Twelve of the fifteen unscheduled shutdowns that had occurred between 1963 and 1968 were caused by NaK leaks or other failures in the NaK system. In addition, it wasn't hot enough. The operators knew that a hotter temperature in the calciner could double the rate at which the liquid feed could be processed in the vessel.

The operator of the WCF, which by this time was the Idaho Nuclear Corporation, decided to replace the indirect NaK system with a direct kerosene combustion system. Engineers refitted the calciner so that kerosene and oxygen could be sprayed into it. Nitrates from the waste feed would ignite it, placing the heat in intimate contact with the moving particles in the bed. This method supplied steady temperatures of 450 degrees C or more. The Safety Analysis Report noted that NaK hazards would be traded for potential--but more improbable--explosions should kerosene leak into a process vessel or piping. Overall, the new system was less hazardous because hydrocarbon fuel piping was more reliable than NaK piping. It also eliminated the nitrogen oxides that the NaK system had sent up the stack as an environmental pollutant.[22]

The heat-source change affected the interior, not the exterior of the building. Pure liquid oxygen was stored in a 6,000 gallon storage vessel 300 feet west of the WCF. The furnace in the NaK handling room was converted to preheat the fluidizing air during the start-up of a campaign. Analog computers, flowmeters, thermocouples, and other instruments were added to

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seven campaigns, see J.E. Johnson and D.J. Bradford, Decontamination of the Waste Calcining Facility--A Historical Review (Idaho Falls: Allied Chemical Report No. ICP-1173, December 1978), p. 11-24; and La Var Zohner, in interview with Susan M. Stacy, March 13, 1998.

[22] C.L. Bendixsen, Safety Analysis Report for the Conceptual In-Bed Combustion System for the Waste Calcining Facility (Idaho Falls: Idaho Nuclear Corporation Report No. CI-1119), p. 1, 27; and Bendixsen, Safety Review Report for the In-Bed Combustion System for the Waste Calcining Facility (Idaho Falls: Idaho Nuclear Corporation Report No. CI-1175, March 1970), p. 1-2. Nitrates in the waste feed interact with the kerosene to produce more benign nitrogen compounds.

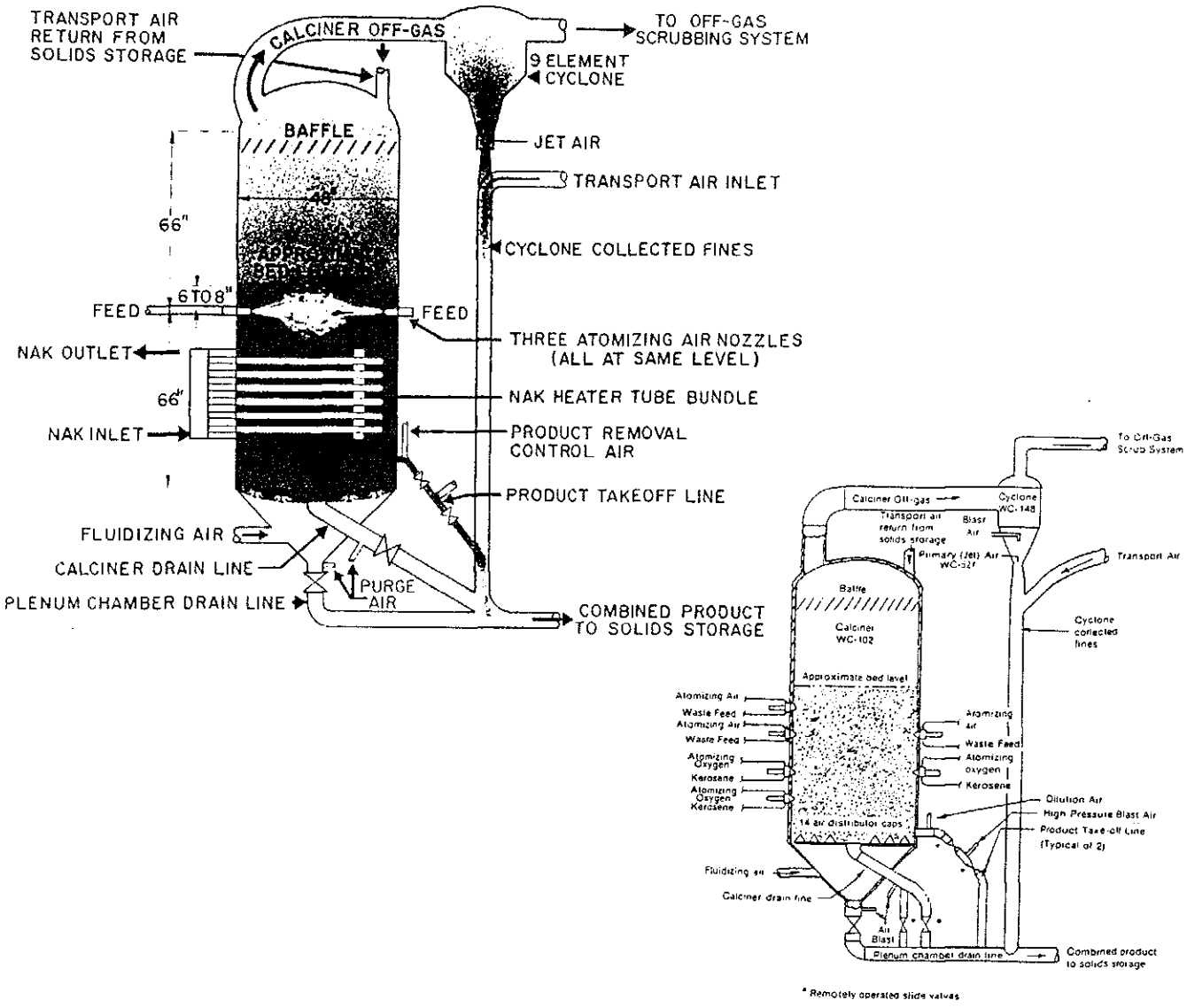

Fig. 14: Diagrams showing calciner vessel with the original NaK heating system and after the it was modified for a direct combustion kerosene heating system.

Source: Childs et al., *The Ninth Processing Campaign in the Waste Calcining Facility* (Idaho Falls: Exxon Nuclear Idaho Report No. ENICO-1100), p. 37; and Phillips Petroleum Company, *Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho* (Idaho Falls: PPCo, no date), p. 25.

the operating system. Emergency shut-down equipment used during the NaK era was adapted readily to the new regime.[23]

On August 3, 1970, the fourth campaign began, and the first use of the in-bed combustion system. It continued without any shutdowns to process 217,000 gallons of zirconium-fuel waste and 7,100 gallons of aluminum-fuel waste. With the job done, the campaign ended on January 5, 1971. Once again, the WCF proved to be reliable, safe, and now, more efficient than before. Processed at temperatures of 500 degrees C, the zirconium waste had been calcined at a greater feed rate than before, and ruthenium releases to the stack were several orders of magnitude less than they had been in the third campaign.[24]

PART EIGHT
THE NEW WASTE CALCINING FACILITY

By 1974 the WCF was starting to show signs of wear. Its designers had not contemplated that the calciner would deal with fluoride waste feed. The small scratches and pits on the many metal surfaces of vessels and pipes attracted deposits of radionuclides that were hard, if not impossible, to remove. Hazards to the crews were increasing at the same time safety standards were becoming more stringent. And more exotic wastes were coming, some of which would challenge the aging facility even more.[25] Congress authorized Fiscal Year 1975 funds to design another calcining facility. The Energy Research and Development Agency, successor to the Atomic Energy Commission, selected the Ralph M. Parsons Company to prepare a conceptual design for the new facility.

Parsons had four main design objectives for the new plant. It must be safer for workers; it should raise the daily process capacity from 1,800 gallons to at least 3,000 gallons per day; it should handle the chemistry of exotic and future waste feeds; and it should discharge into the atmosphere even less radioactive particles than before--to a standard "As Low as Practicable." All features of the operation were open for improvements: the heating system, the handling of ruthenium, the reduction of fluoride corrosion, even the shape of the calciner vessel (would a conical

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[23] Bendixsen, p. 6-7.

[24] J.A. Wielang, The Fourth Processing Campaign in the Waste Calcining Facility, FY-1971 (Idaho Falls: Allied Chemical Corporation Report No. UC-70, March 1972), p. iii.

[25] Allied Chemical, p. 16.

shape be better than a cylindrical shape?). All parts, moving or otherwise, were candidates for replacement if better materials or better engineering could produce economies or efficiencies--scrubbing systems, filters, nozzles, feed metering controls, instrumentation, and sampling.[26]

In many ways, the design of the new facility was a tribute to the old. It, too, was in a single building with the process cells below grade. Shielded equipment cubicles next to the cells housed high maintenance items--although this time they had air locks. Back-up equipment was installed from the start so that in the event of a failure, a campaign would not have to be shut down. Heavy equipment was arranged for crane access. Although more maintenance chores were designed for remote operation, direct maintenance still had a part. However, the second time around, the calciner and other cells had shielding windows and "master/slave" manipulators for remote replacements, adjustments, and decontamination. And anything that weighed more than thirty pounds (which was the weight limit for the remote manipulators) had lifting eyes, lugs, rails, or beams: cranes would do all the heavy lifting in the new plant. Hatches would still cover the cells, but they would be sectioned so that only a portion of the hatch could be lifted as needed. Also, hatches had small plugs for the entry of small television cameras. Federal rules required that the building be designed with a view toward its ultimate decontamination and decommissioning.[27]

Fluor Engineers and Constructors completed the final design for the New Waste Calcining Facility in September 1975. Its inaugural campaign began in September 1982.[28]

PART NINE
THE LAST CAMPAIGN

While awaiting the new calciner, CPP engineers continued to experiment and adapt the calcining process to solve new problems. Typically this work involved determining what "blend" of waste liquids could be processed without compromising the calcining

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[26] Allied Chemical, p. 16-18.

[27] R.R. Smith, Design Criteria for New Waste Calcine Facility (Idaho Falls: Allied Chemical Corporation, US AEC Report ACI-164, 1974), p. 1-5. See p. 99 for criteria under Chapter 10, Code of Federal Regulations, Part 50, Appendix F[2] for decommissioning criteria.

[28] Chem Plant History, pamphlet, no date.

equipment or the stability of the calcine product in the storage bins. One example of this was the special reactor fuel developed by the U.S. Air Force and the AEC for Project Rover.

The Rover mission, which began in 1957, was to use a nuclear reactor to propel space vehicles using an open-cycle rocket.[29] A nuclear reactor would heat a propellant gas, which gas would be ejected through a nozzle, thus producing thrust. To get the fuel hot enough, the reactor had to operate at an extremely high temperature--over 3,500 degrees F. It was more than a challenge to find reactor fuel and structural materials that would retain their mechanical integrity in such heat, to say nothing of melting. Testing of reactor designs and components began in 1959. The Rover engineers eventually fabricated fuel elements that would hold up.[30]

The elements were made of uranium dicarbide particles dispersed in a matrix of solid graphite. The particles were coated with a pyrolytic carbon, and the surface of each element had a protective coating of niobium or niobium carbide. When the Rover tests had run their course, the AEC sent the reactor fuel to the NRTS to recover its Uranium-235, and thence to calcine the waste.[31]

After CPP-601 had extracted the uranium from the fuel, 125,000 gallons of liquid waste remained. The WCF engineers had found, via experiments in small-scale laboratory calciners, that pure Rover waste could not be calcined. Instead of producing the preferred small granules, the solid particles stuck to each other in large clumps and clogged the process pipe. Before long, the calciner "bed" was depleted of grains upon which fresh feed could adhere. The niobium was the main complicating factor. It reacted very differently when calciner conditions were only slightly

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[29] The National Aeronautics and Space Administration (NASA) eventually replaced the Air Force.

[30] For an early historic overview of Project Rover, see William C. House, "The Development of Nuclear Rocket Propulsion in the United States," a paper presented to the British Interplanetary Society Advanced Propulsion Symposium, London, England, October 9, 1963. See also Hogerton, p. 486-488; and Space Nuclear Propulsion Office, Nuclear Rocket Development Station, undated pamphlet (Nevada: SNPO), p. 1-2.

[31] Niobium, also called Columbium, improved corrosion resistance and the stability of uranium. It was used sparingly because it absorbed neutrons and was expensive at $80 a pound in 1963. Hogerton, p. 104.

different. Even variations of 10 degrees of temperature were enough to make it misbehave.

Therefore, the chemists experimented with different blends. They found that if at least half the feed recipe consisted of zirconium waste, they could calcine all of it successfully. They also learned that the storage temperature in the bin sets should be kept below 700 degrees C because the calcine particles began to stick together slightly.[32] With such research behind them, the Rover waste was confidently dumped into a liquid waste storage tank and "blended" with the more standard wastes. As it happened, the Rover waste probably was added to the tanks too late to be calcined by the old calciner.[33]

However, other well-researched "blends" were processed in the WCF's ninth and last calcining campaign, which began on June 16, 1979, and ended on March 16, 1981. A blend of about 454,600 gallons of zirconium fluoride and 22,300 gallons of sodium waste entered the Old WCF as a liquid and left as a solid. This campaign was not the smoothest run. A balky distributor plate beneath the calciner vessel failed to distribute hot air to the bed and caused several shutdowns. Operating on-stream efficiency was only 46 percent.

When it was over, the WCF continued in partial service until 1987 as a pre-treatment facility for liquid waste headed for the New WCF. The feed passed through the system of heat, vessels, and pipes for partial evaporation and concentrating of the wastes. After this use of the facility ended in 1987, the facility and system went completely out of service. Even so, the building could not be completely abandoned. To prevent contaminated air migrating into the environment, a ventilation system drew the air to a central air cleaning system (atmospheric protection system) within the CPP complex.[34] The next phase planned for the WCF was cleanup, deactivation, and closure.

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[32] The Rover calcine ended up in Bin Sets No. 3 and No. 4, where it was deemed that overheating of the Rover constituents would not occur. Allied Chemical, Pilot-Plant Development of a Rover Waste Calcination Flowsheet (Idaho Falls: Allied Chemical, April 1978), p. iii, 1-2, 19-21.

[33] La Var Zohner, telephone interview with Susan M. Stacy, March 13, 1998. Zohner, now retired, was WCF Supervisor in the 1970s.

[34] Closure of the Waste Calcine Facility (CPP-633), INEL: Environmental Assessment (Idaho Falls: US DOE/Idaho Operations Office Report No. DOE/EA 1149, 1996), p. 2.

PART TEN
DEACTIVATION AND THE RCRA CAP

Even in its last days, the Old WCF was breaking new ground in nuclear history. In the remediation and clean-up phase of the atomic age, the WCF will be the first "closure by in-place entombment with a RCRA cap" in the nation.[35]

The nuclear research mission of the United States, which began with the decision to make an atomic bomb during World War II, left a "legacy" of hazardous sites and contaminated wastes at most national laboratories and production sites in the country. The environmental movement of the 1960s and 1970s reacted against the accumulation of nuclear (and other) hazardous wastes. Citizens passed laws at federal and state levels to control, remediate, and prevent the reoccurrence of such hazards.[36]

Several of these laws now govern the disposition of the Old Waste Calcining Facility. The Resource Conservation and Recovery Act of 1976 (RCRA) regulates owners of hazardous waste, setting safety requirements and parameters for its disposition and storage. It defines and describes hazardous "units" that must be dealt with under various clean-up schedules. It prescribes protective standards--such as "caps" or covers on waste sites intended to prevent the migration of hazardous materials into the water supply, soils, or air.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA, also known as "Superfund") provides mechanisms for the Environmental Protection Agency to force agencies such as the DOE to clean up sites where accidents or usage have contaminated the soil or water. Investigations have identified four such places near the WCF building. One of them is a patch of contaminated soil near the foundation, and the other three involve a below-grade off-gas duct surrounding three sides of the WCF building.[37]

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[35] Dennis Peterson, LMITCO Decontamination and Demolition staff, in telephone interview with Susan M. Stacy on August 21, 1997.

[36] For a description and discussion of these, see US DOE Office of Environmental Management, Linking Legacies, Connecting the Cold War Nuclear Weapons Processes to their Environmental Consequences (Washington, DC: DOE Report No. DOE/EM-031).

[37] Idaho National Engineering Laboratory, Closure of the Waste Calcining Facility (CPP-633), Idaho National Engineering Laboratory, Draft Environmental Assessment (Idaho Falls: INEL

The State of Idaho passed a Hazardous Waste Management Act in 1983 which incorporated procedures and standards for dealing with asbestos and radioactive hazards set forth in CERCLA. [Idaho Code: 39-4401.]

And finally, whenever DOE undertakes activities that could impact the environment adversely, it must follow the National Environmental Protection Act of 1969, examine the impacts of alternative choices before it acts, and submit to public review.

As these laws weigh upon the Old WCF, three authorities had to agree upon the disposition of the building: DOE, the State of Idaho, and EPA. DOE studied the relative risks and costs of three alternatives for "closing" the Old WCF: closing it "in place," removing its contaminated parts for disposal at a radioactive waste disposal facility, or doing nothing.

After examining costs and hazards, DOE recommended the "closure-in-place" alternative because it minimized worker exposure to radiation and minimized the waste volume requiring disposal. Moving highly contaminated equipment and chunks of concrete to a burial ground appeared to be less practical than sealing the building and treating it as its own small hazardous waste landfill. Closure-in-place was estimated to cost $9 million; partial removal, $18 million. Taking "no action" would require continued surveillance of the building estimated to cost $400,000 for at least 100 years or more.[38]

On August 11, 1997, the three authorities signed a document agreeing to the "closure-in-place" alternative and began the clock ticking on a two-year schedule to complete the closure.[39]

The closure-in-place procedure requires a series of actions in sequence. First, the below-grade portion of the building is isolated from the many utility and process systems that brought air, water, electric power, feed, waste, or solids into or out of the WCF. Then utility and power lines are disconnected, and each conduit or pipeline filled with grout. Every vessel and every pipe in the below-grade section of the building is filled with grout. Finally, every cell, room, and corridor is filled with

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Report No. DOE/EA-1149, 1996), p. 4.

[38] Draft Environmental Assessment p. 5-9.

[39] The closure plan is described in Idaho National Engineering Laboratory, HWMA Closure Plan for the Waste Calcining Facility at the Idaho National Engineering Laboratory (Idaho Falls: INEL-96/0189).

grout. The grout, once cured, will transform the building into a massive monolith of concrete, eliminating air pockets, and immobilizing everything within the monolith.

The above-grade part of the building will be decontaminated, and since its asbestos constituents were removed prior to the August 11 agreement, jaw-like crushers will reduce the building to standard-sized rubble. This rubble will be spread over the grouted below-grade structure, creating a pile three to four feet high. Grouting will then fill the voids and spaces within this rubble pile. Above all of this and for the final touch, a reinforced concrete cap--constructed to RCRA standards and thus a "RCRA cap"--will be placed as a neat smooth-surfaced rectangle, extending approximately five feet beyond the monolith in all directions, and sloped slightly for the sake of drainage. Annual inspections will check for and repair cracks or degraded seals. Grading and asphalt around the cap will deflect stormwater run-off away from the cap. This arrangement of a RCRA cap over a closed-in-place structure is believed to be the first undertaken in the country.[40]

Should the conditions of present civilization change dramatically and result in this desert site being abandoned before the radioactivity has decayed to harmless levels, the capped structure should nearly eliminate the chance that a wandering passerby would experience harmful radiation exposures from the remains of the Old WCF.

PART ELEVEN
SIGNIFICANCE/CONTEXT OF THE OLD WASTE CALCINING FACILITY

In November 1990, President George Bush formally declared the end of the Cold War. The race to stockpile nuclear weapons ended with it. With these fundamentally changed world conditions, the government no longer needed to operate nuclear reactors to manufacture plutonium for weapons. The supply of the world's natural uranium appeared to be sufficient for nuclear power reactors. Furthermore, fears that "rogue states" or terrorists might illegally acquire recovered plutonium to make weapons have grown over the last twenty years. In 1992, the United States decided that it would no longer recover uranium from spent nuclear fuel.[41]

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[40] Dennis Peterson, August 21, 1997.

[41] For an account of government nuclear energy policy, see Terrence Fehner and Jack M. Holl, Department of Energy, 1977-1994, A Summary History (Washington, DC: Department of Energy

As this policy affected the Chemical Processing Plant, it meant that the reprocessing of spent nuclear fuel to recover uranium ceased. It followed that the waste stream supplying feed planned for calcination dried up. Spent fuel now is destined to be stored in shielded dry storage vaults to await "final" disposition to a waste repository, possibly to be developed in Yucca Mountain, Nevada.[42] Indeed, spent fuel continued to arrive at INEEL from the US Navy, which still maintained a fleet of nuclear-powered submarines and surface ships, and from other sources.

The continued arrival of US Navy fuel proved to be controversial in the State of Idaho. After lawsuits and protracted negotiations, Governor Phil Batt of Idaho, the DOE, and the US Navy signed an agreement to limit such shipments into the state, to provide dry storage for them, and to transport it back out of the state by 2035.[43]

The same agreement also set forth a schedule for calcining the remaining liquid waste in CPP's storage tanks. In 1997, the New Waste Calcining Facility began a campaign to accomplish a portion of this task--and will continue until the last tank at INEEL is drained of its liquid wastes.

The INEEL was not the only AEC facility to generate high-level liquid waste. Three others--at Hanford, Washington; Savannah River, Georgia; and West Valley Demonstration Project, New York--also reprocessed spent fuel. In contrast to these, the AEC's Hanford and Savannah River produced far more waste than INEEL, while West Valley, which was a quasi-commercial business that reprocessed civilian reactor fuel for a short time, produced

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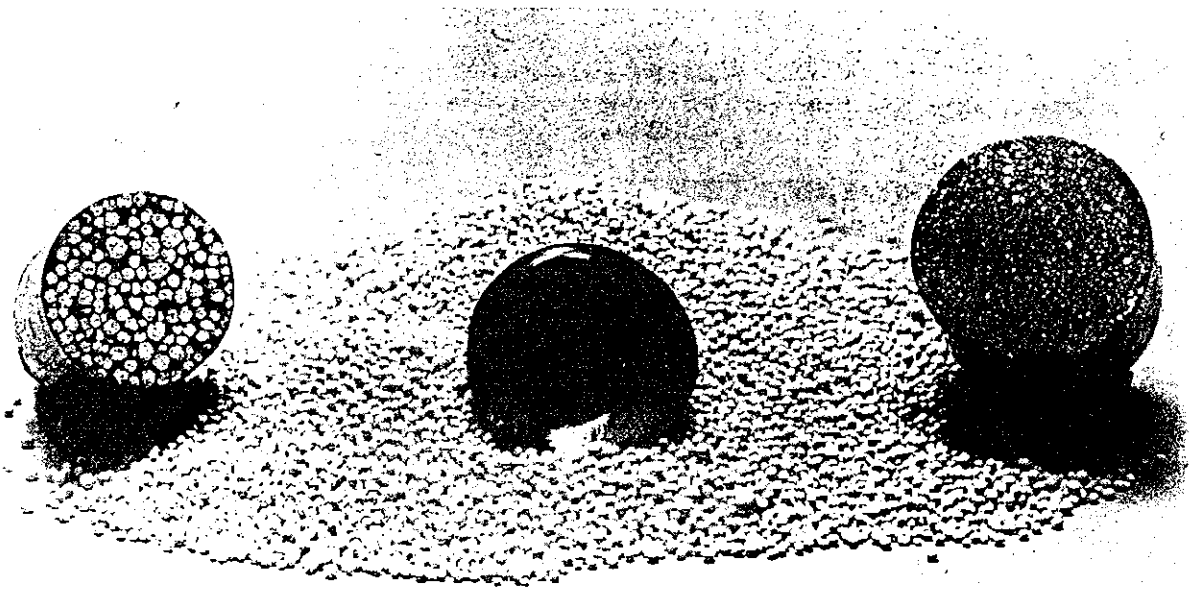
Report No. DOE/HR-0098, 1994), p. 53-76, "Part VI, The Bush Administration, 1989-1993.

[42] The Nuclear Waste Policy Act of 1982 ordered the DOE to site, design, build, and operate a geological repository for permanent disposal of spent fuel and high level waste. A site in Yucca Mountain is under study as of 1997.

[43] "Settlement Agreement between the State of Idaho, the Department of Energy, and Department of the Navy, October 16, 1995, to resolve issues in the action of Public Service Company of Colorado v. Governor Phil Batt [of Idaho]," No. CV91-0035-S. EJL (D.Id.) and US v. Batt, No. CV-01-0054-S-IJL (D.Id.) Section C.1 of the agreement states that all spent fuel from the Navy and from Three Mile Island will be removed from Idaho by 2035.



The product of calcining is a dry granular material called *alumina*. It can be further contained or stabilized in an aluminum (left), glass (center), or sulfur (right) matrix.

Source: Phillips Petroleum Company, *Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho* (Idaho Falls: PPCo, no date), p. 28.

less.[44] These facilities embarked on different strategies for converting liguid wastes to other forms. Hanford isolated Strontium-90 and Cesium-137 in highly concentrated bricks for lease to industries that needed intense radiation sources.

The timing of development and insufficient financing explain why Savannah River and West Valley did not calcine their high-level wastes. In both cases, decision-makers chose to build storage tanks out of carbon steel instead of stainless because it was substantially cheaper. Carbon steel is considerably more vulnerable to acid corrosion than stainless. Therefore, chemists at those plants (and at Hanford, where tanks built during World War II also were made of carbon steel) added sodium hydroxide to the acidic waste to neutralize it. This caused solids to precipitate into an insoluble sludge in the bottom of the tank. The sludge contains most of the radioactivity. It cannot be re-dissolved in nitric acid without destroying the carbon steel container as well. The sludge was produced without a plan or any idea of how the sludge could ever be removed from the tanks; yet it was known that the tanks would eventually corrode and leak. The problem of retrieving this material and transforming it to a safer, more suitable form for storage continues to pose a serious problem, the resolution of which is expected to cost billions of dollars.

West Valley opened in 1966 as the first private nuclear fuel processing plant in the country. The AEC's Savannah River plant had begun operating in the early 1950s and had emulated the neutralization process originated at Hanford in the 1940s, although it did improve upon Hanford's single-wall design for the tanks by constructing double-wall tanks. While West Valley was in its design stages, the experience in Idaho was considered too new--its first hot calcining campaign ended in October 1964. And the much more costly stainless steel storage continued. So West Valley stuck with the carbon steel/neutralization system, and the AEC licensed it.[45]

Chemical research and engineering has had to contend with sludge, salt cake, and other substances at these other plants. The sodium additive provides a complication not present in most of the liguid presented to the Idaho calciner; it prevented satisfactory calcination. Processes for vitrification of the sludges finally were developed. Savannah River and West Valley

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[44] See Linking Legacies, p. 36.

[45] Richard K. Lester and David J. Rose, "The Nuclear Wastes at West Valley, New York," Technology Review (May 1977), p. 20-23.

waste are being vitrified prior to shipment to whatever "permanent" repository is selected. Specific final forms for INEEL and Hanford wastes are still in the planning stages.[46]

The quest for a workable calcining process at INEEL began early. Once operating, it continued reliably and operated regularly. Partly because of it, the INEEL has no record of liquid waste contaminating the soil or groundwater from tank leakage, a record not shared by the other sites. It proved a principle just as the commercial nuclear power industry was becoming an economic reality--but not early enough to handle wastes at the three other places which had committed to older and much more troublesome and hazard-prone techniques. Nevertheless, calcining constituted a significant reason for optimism in the pursuit by scientists of a safe nuclear-fuel cycle. Apparent high costs in the development and operation of the calcining process may prove to have been the lowest-cost long-term choice.

Recognizing its contribution to American nuclear history, the American Nuclear Society designated the Old WCF as a Nuclear Historic Landmark in September 1993. The award plaque read, "The first radioactive treatment center to solidify liquid wastes and reduce volume. It operated successfully from 1963 to 1981."

Historians and the people who were associated with the Old Waste Calcining Facility can hope that this plaque will be placed near its RCRA Cap as the monument for its closure.[47]

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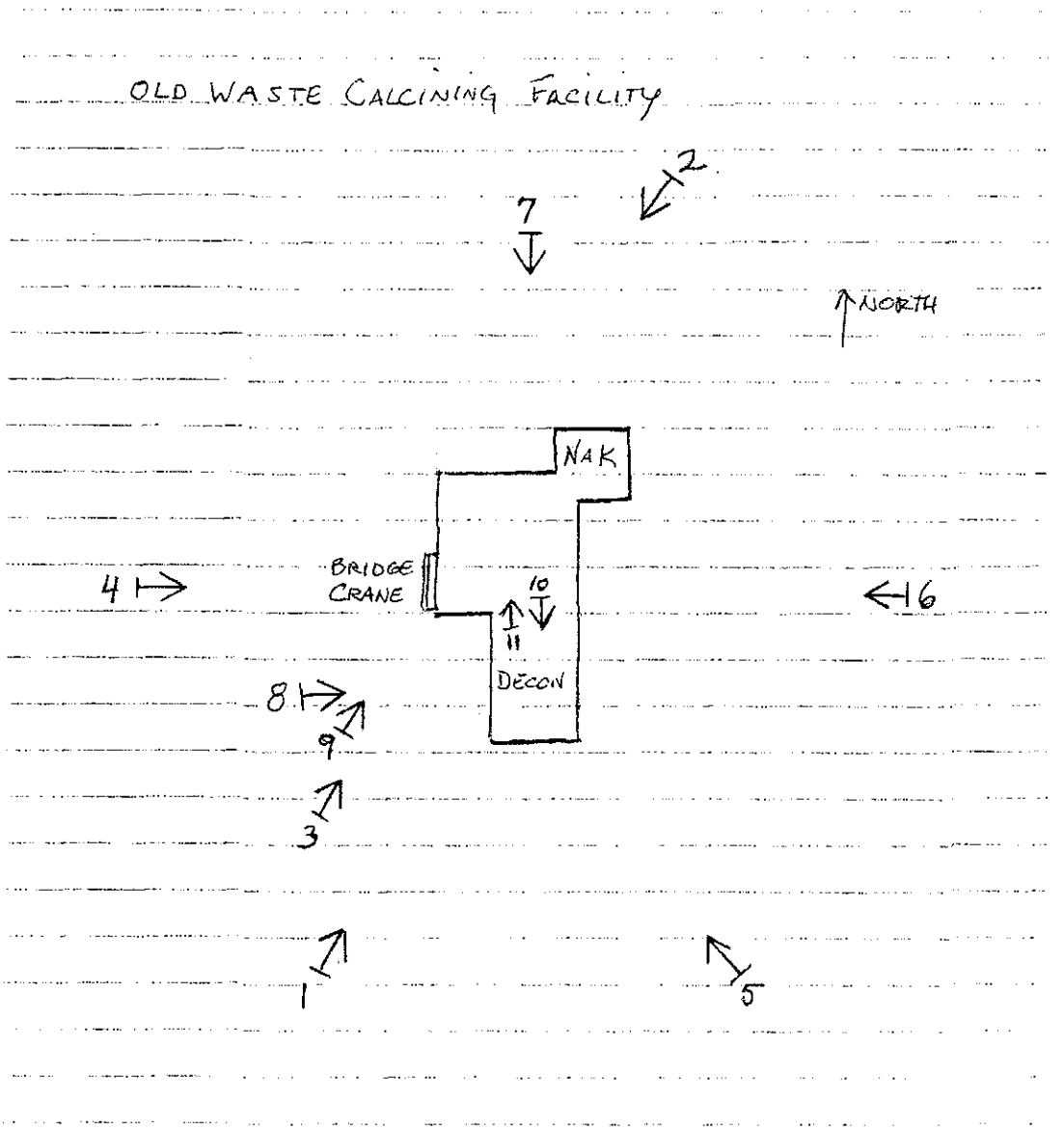
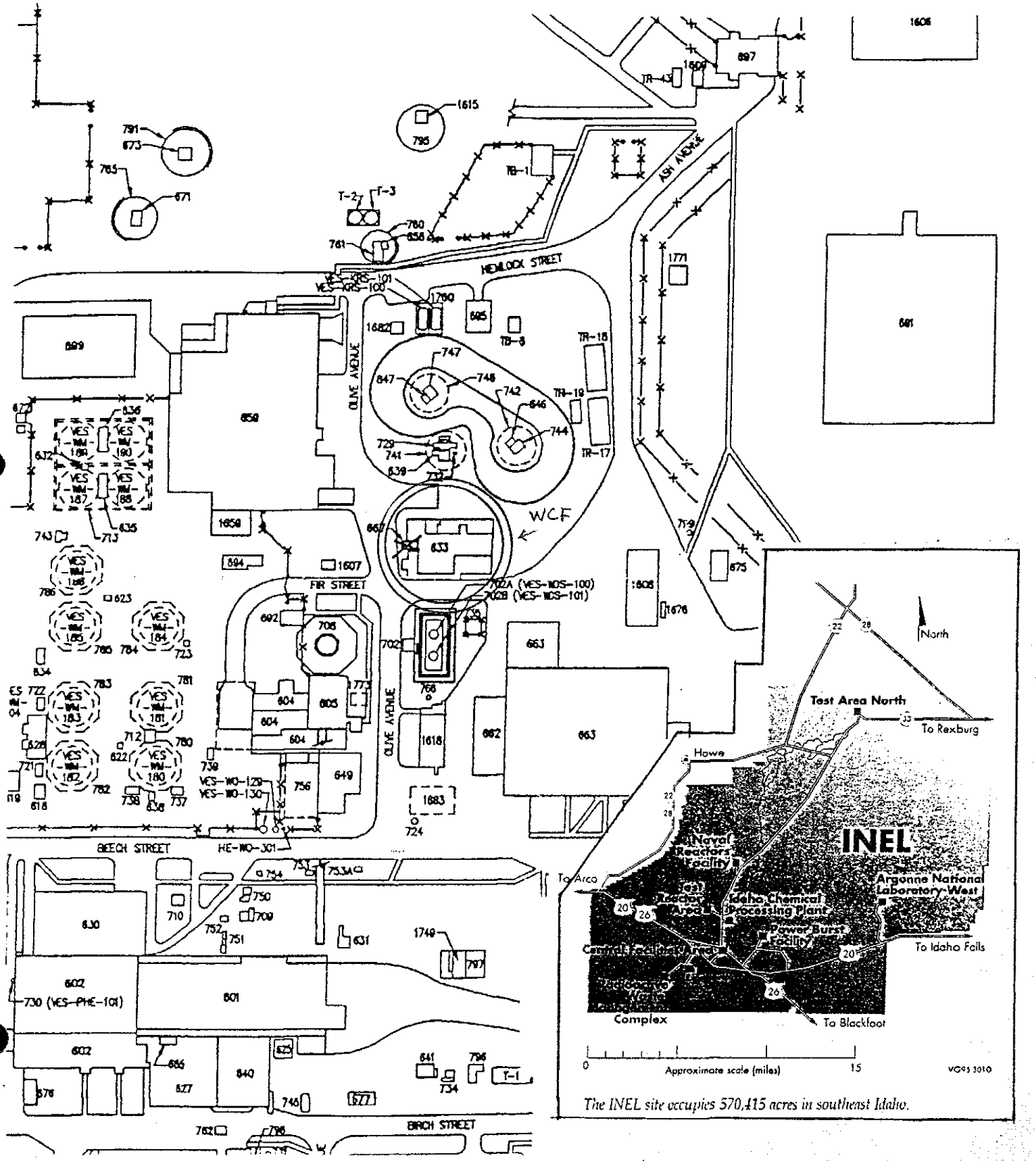
[46] Linking Legacies, p. 38. It should be noted that the Eighth and Ninth Campaigns at the Old WCF successfully calcined sodium-bearing blended loads.

[47] The American Nuclear Society designated the WCF as a Nuclear Historic Landmark in September 1993. The plaque says, "The first radioactive treatment center to solidify liquid wastes and reduce volume. It operated successfully from 1963 to 1981."

Appendix A: Photo Key Map for HAER Photos ID-33-C-1 through -11



Appendix B: Vicinity Map and Neighborhood of the WCF at CPP



Appendix C: Detailed Description of the Waste Calcining Process

The basic process used in the Waste Calcining Facility is known as fluidized bed calcination. The bed consists of previously calcined granular material (or granular aluminum oxide, as a starter) which is kept in motion by a flow of heated air from beneath. The bed is heated to a temperature of 750 degrees F by this air and by hot liquid metal (a sodium-potassium alloy called NaK) that circulates through bayonet tubes in the bed.

The liquid waste enters the bed through pneumatic atomizing jets, sprays as tiny droplets onto the solid particles of the bed, is almost instantly dehydrated, and is decomposed from nitrates to oxides by the heat. Nitrogen oxide gases and water vapor are given off. The solid product consists of about 89 percent aluminum oxide, 10 percent other metallic oxides, and 0.6 percent fission product oxides.

In the production plant, the NaK liquid metal that heats the fluidized bed is heated in an oil-fired furnace. The calciner vessel is approximately 18 feet high. The fluidizing air enters through 14 holes in a distributing plate at the bottom of the vessel. The superficial fluidizing air velocity (or calculated velocity of air flow at operating temperature and pressure with no bed present) is one foot per second.

The size of the bed particles is controlled by regulating the air-to-liquid volume ratio at the waste feed nozzles; the ratios are between 500 and 650 to 1 for start-up. The desirable average size for the bed particles is 0.5 to 0.6 millimeters in diameter; this size is a compromise between smaller particles that would give better heat transfer and larger particles that would be less apt to be carried away with the off-gas.

The form of alumina (aluminum oxide) created in the bed is important; the amorphous form is preferred to the alpha form because the amorphous form is more soluble in the off-gas scrubbing solution and is more resistant to shattering into tiny particles than the alpha form. Thus, with an amorphous alumina product, off-gas cleanup and system decontamination problems are minimized, and erosion of pumps, valves, and lines in the off-gas scrubbing system is reduced.

The waste feed rate to the calciner is 80 to 100 gallons per hour, three-fourths of which is waste from the underground storage tanks of the Chemical Processing Plant (CPP), and the rest is recycled waste from the calciner's off-gas scrubbing system.

The solid product leaves the calciner vessel through a 1/2 inch line near the bottom, impelled by the bed pressure. A small air line near the point of exit regulates the flow. The product passes from the 1/2 inch line into a 3-inch line through which it is blown to storage bins. The rate of solids production is 50 to 60 pounds per hour, of which about half is taken directly

from the bed, and the remainder is recovered from the off-gas stream by a primary cyclone.

The cleanup of the off-gas from the calciner vessel involves a large part of the equipment in the Waste Calcining Facility. The gas is moved through the cleanup system by induced draft blowers that force the gas to the 250-foot stack at the CPP.

The first stage of cleanup is the primary cyclone. This cyclone is a multiple unit consisting of nine parallel cyclones of 4-inch diameter. The solids that are separated from the gas by the cyclone are blown to storage with the product from the calciner vessel.

The gas leaves the cyclone with a content of about 10 pound of solids per hour. The next stage is a quench tower where sprays of scrub solution cool the gas down from 750 to 140 degrees F. The gas then proceeds to a venturi scrubber. The quench tower spray solution circulates to the venture throat where it is dispersed into many droplets which capture most of the remaining solids in the gas. Most of the solids go into solution; only about 0.02 percent by weight remain as a slurry. The discharge of the venturi scrubber goes to two cyclones in series where the liquid and slurry are separated from the gas; the liquid and slurry then go to a scrub solution surge tank. From the surge tank, 20 to 30 gallons of liquid per hour are recycled to the calciner's waste hold tank. The off-gas leaves the scrubbing system with less than 0.02 pound of solids per hour.

The gas next goes through a heater to prevent condensation, and goes to silica-gel adsorbers, the main purpose of which is to remove ruthenium. Ruthenium is the only fission product that forms a volatile compound during calcination, and much of the ruthenium passes through the cleanup system as a gas until being adsorbed on the silica gel. The silica gel also traps some remaining solids, reducing the solids in the gas to about 0.002 pound per hour.

After going through another heater the gas goes to the last stage of cleanup, which consists of three parallel filter units known as AEC-type high-efficiency filters. Each has a fiberglass prefilter followed by a glass-asbestos final filter. After the gas passes through these filters the solids in the gas amount to less than 0.000001 pound per hour. This rate is considered very satisfactory. At the liquid waste concentrations presently handled by the calciner, the fission product content is far below the limits set for satisfactory operation by the Radioactivity Concentration Guide of the Federal Radiation Council.

After leaving the filters, the gas, which consists of about 4 percent nitrogen oxides, about 12 percent water vapor, and the remainder air, is sent up the 250-foot stack of the CPP for discharge to the atmosphere.

Meanwhile the solids go to storage. The initial storage facility consists of four sets of annular bins in an underground concrete vault. Each

set of bins is 20 feet high and consists of three nested bins: a center bin 3 feet in diameter, surrounded by a 2-inch wide cooling annulus and 2-foot wide storage annulus, surrounded by still another 2-inch wide cooling annulus and 2-foot wide storage annulus. The four sets of bins have capacity for 7,800 cubic feet (or about 400,000 pounds) of calcined solids.

The solids transport line from the calciner feeds into a cyclone separator at the bins. The transport air recycles to the calciner vessel while the departed solids fall into a distribution header. The solids flow from the header down tubes into the bins. After each bin fills, the solids fill its distribution tubes, and the level of solids in the header rises until the solids can flow down next higher series of tubes into the next bin. The bins are thereby filled without need for any mechanism to divert the flow.

Cooling air circulates through the annuli between the storage spaces by natural convection. Blowers are available for forced convection if needed. With waste that has had several years' aging, natural convection is sufficient to keep the temperature of the stored solids well below 750 degrees F.

Source: National Reactor Testing Station, Idaho Chemical Processing Plant, Idaho Operations Office of the US AEC. No date. The description pertains to the original NaK heating system for the calciner.

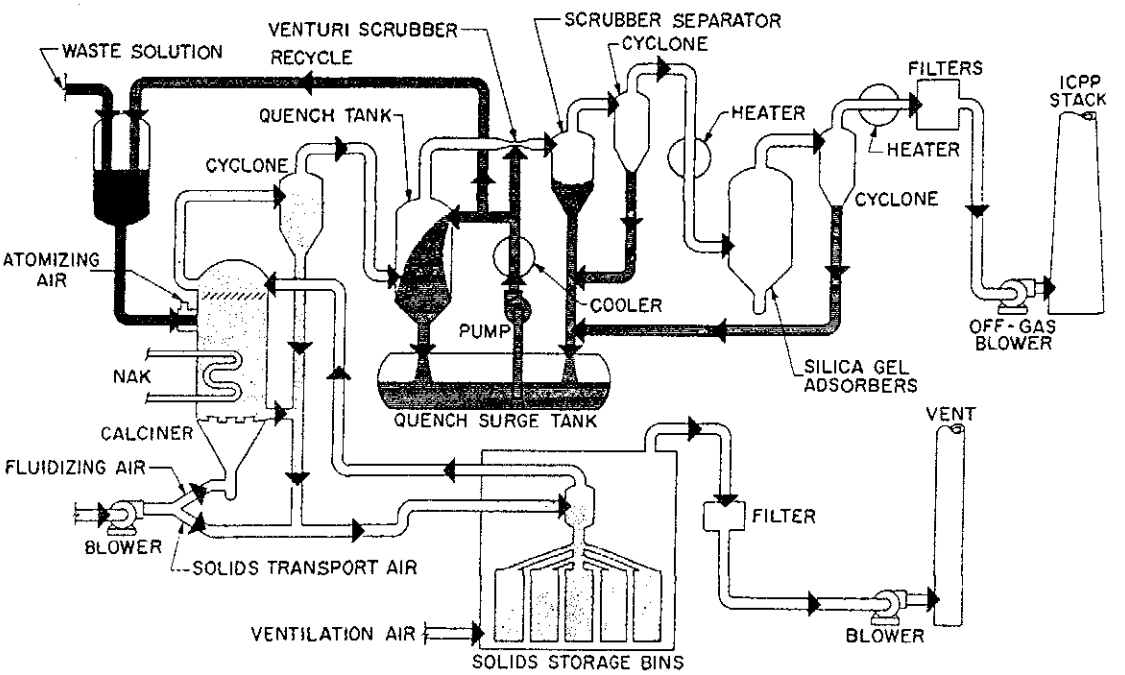


Fig. 15: Simplified view of the calcination process

Source: Phillips Petroleum Company, *Idaho Chemical Processing Plant, National Reactor Testing Station, Idaho* (Idaho Falls: PPCo, no date), p. 26.

Appendix D: Chronology of WCF Campaigns

Processing Campaign	Waste Salutian Calcined	Volume of Liquid Waste Calcined liters	gal
First (Dec. 1963 ta Oct. 1964)	Aluminum	1937920	51 2000
Secand (April 1966 to March 1968)	Aluminum	3236180	855000
	Zirconium Fluoride	408780	108000
Third (Aug. 1968 ta June 1969)	Aluminum	56780	15000
	Zircanium Fluoride	1196060	31 6000
Fourth (Aug. 1970 to Jan 1971)	Zircanium Fluoride	851630	225000
Fifth (Sept 1971 ta May 1972)	Aluminum	295230	78000
	Zirconium Fluoride	836480	221000
	Stainless Steel Sulfate	18925	5000
Sixth (May 1973 ta May 1974)	Aluminum	41630	11000
	Zirconium Fluoride	1029520	272000
Seventh (May 1975 ta Jan 1977)	Zirconium Fluoride	1420510	375300
Eighth (Aug. 1977 ta Sept. 1978)	Zirconium Fluoride	1012490	267500
	Sodium Bearing (3.5:1 Blend)	732020	193400
Ninth (June 1979 to March 1981)	Zirconium Fluoride	1720434	454600
	Sodium Bearing	84394	22300

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